HUXLEY

AUTOBIOGRAPHY AND ESSAYS

MATTHEWS

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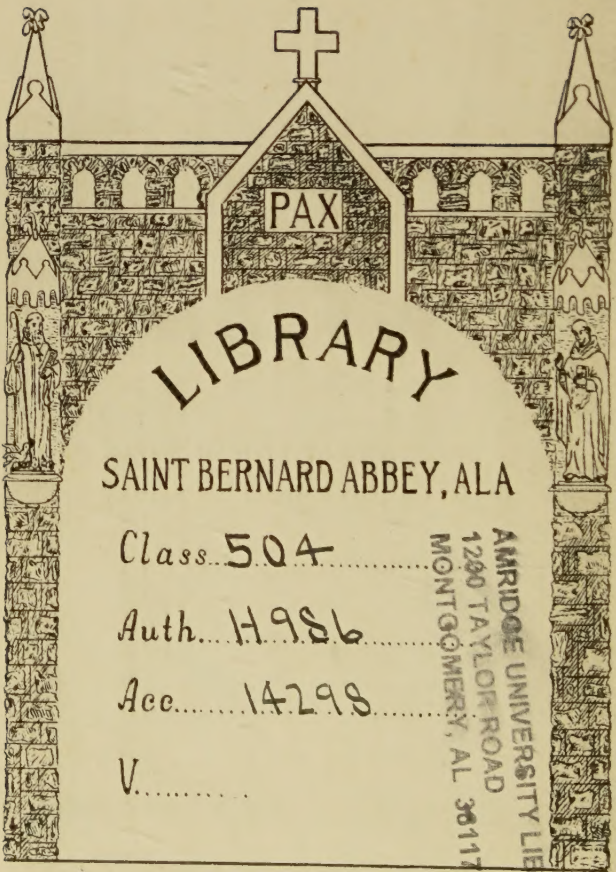
Editor-in-Chief



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LIVING LITERATURE SERIES

RICHARD BURTON, PH.D., Editor-in-Chief

AUTOBIOGRAPHY AND ESSAYS

BY

THOMAS HENRY HUXLEY

1825-95

EDITED BY

BRANDER MATTHEWS

PROFESSOR OF DRAMATIC LITERATURE
COLUMBIA UNIVERSITY

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Huxley, Thomas Henry, 1825-1895.
Autobiography and essays.

THE GREGG PUBLISHING COMPANY
NEW YORK—CHICAGO—BOSTON—SAN FRANCISCO
LIVERPOOL

cp 1919

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PREFACE

The literature that lives has nothing to do with Time. It may be a farce by Aristophanes, a speech of Cicero's, a canto of Dante's song, or a story by O. Henry; it is always a question of vitality. On the contrary, a piece of writing that lacks this precious, preservative quality dies the day it is born. The idea that because a poem, a tale, a play, or an essay was written a hundred or a thousand years ago, it must necessarily be dead, is quite false. Always the question is: Has it charm, beauty, power, human meaning? If it has it will survive; if it is without these saving graces, it not only will not last, but never *was* alive.

We speak of the "dead languages," and the familiar phrase is right in the sense that the tongues themselves in the form they once took are no longer vital on the lips of men. But the thought and feeling embodied in the words of great writers during the so-called classic days of Greece and Rome are truly and splendidly alive to-day, for the simple reason that they were alive then; and are so true to the universal experience of mankind, and so beautiful in their expression, that Time cannot touch them nor age wither their "infinite variety."

The books of the present series are vital for this reason and in this sense. They belong, to be sure, to the modern period and do not go further back than the eighteenth

century; most of them fall in the nineteenth or twentieth century. But they are selected not because they are of this or that period, but primarily for the reason that they are fine examples of the art of letters, and illustrate what *living literature* is and always will be, so long as men can read and think and feel the force and attraction of winged words, couched in the noble tongue which was native to those who use it, and is the priceless heritage and possession of all who communicate their thought in English speech.

The first half-dozen volumes of the series offer authors, British or American, who are strictly contemporary. Interest in writers of our own day naturally precedes interest in the older, even standard writers. So far as appeal is concerned, literature, like charity, begins at home, both as to time and place. Later, some of the elder masterpieces will be offered, like a novel of Scott's, or George Eliot's, or a play by Sheridan or Goldsmith. But it should be realized and recognized that the work of modern men such as Stevenson, or Huxley, can lay claim to equal consideration so long as it is sound as art and sane and tonic in the representation of life. An author of to-day is not of necessity to be treated as a suspect, although he has not so long been tested by critical opinion. It is believed that the contemporary writers included here have produced masterpieces deserving inclusion in any fair, broad-minded, and enjoyable study of the native letters. That is why they are presented herewith, and given prominence.

R. B.

T. H. Huxley

THOMAS HENRY HUXLEY

I

Thomas Henry Huxley was a man of science who was also a man of letters; and there are very few scientists who have attained the literary skill which Huxley acquired by persistent endeavor—by making sure, first of all, that he had something to say, and then secondly, by taking the utmost pains to say this with absolute precision. It was because he was a man of science that, as a man of letters, he never descended to "fine writing," falsely so called. He was not one of those often deluded writers who are like savages, "not content," as Sir Philip Sidney said, "to wear earrings at the fit and natural place of the ears, but they will thrust jewels through their noses and lips because they will be sure to be fine."

He never constructed his ornament, but he often decorated his construction by illuminating figures of speech, always pertinent to his theme. He declared his belief that "science and literature are not two things but two sides of the same thing"; and he put this principle into practice. "A good writer," so Brunetière asserted, "is simply one who says all he means to say, who says only what he means to say, and who says it exactly as he means

to say it." In other words, Huxley is unfailingly conscientious and unfailingly clear. Indeed, he is as clear as Macaulay, who is a master of clarity, but Huxley never sought the glittering effects which we cannot fail to discover in Macaulay's serried sentences—"marshall'd battalions, bright in burnished steel."

Huxley is a man of science with that ingrained desire to be exact and with that abiding abhorrence of any statement not mathematically demonstrable, which are the precious possessions of the men of science and which are only rarely achieved by the men of letters, often betrayed into exaggerated statements by the sound of their sentences, by the color of their words, and by their artistic delight in verbal artifice. "So far as I know myself," he declared in 1891, only four years before his death, "after making due deduction for the ambition of youth and a fiery temper, which ought to (but unfortunately does not) get cooler with age, my sole motive is to get at the truth in all things"; and we may add that his sole motive in writing was to set forth the truth, as he saw it.

In an address on "Universities, Actual and Ideal," which he delivered in 1874 as Lord Rector of the University of Aberdeen, he asserted that in a university the very air the student breathed "should be charged with that enthusiasm for truth, that fanaticism of veracity, which is a greater possession than much learning; a nobler gift than the power of increasing knowledge; by so much greater and nobler than these, as the moral nature of man is greater than the intellectual; for veracity is the heart of morality."

It is because Huxley himself was endowed with the enthusiasm for truth and the fanaticism of veracity, because he was never carried away by any exuberance of verbosity, because he was ready to stand cross-examination on every statement he made, because he was sincere and straightforward, that he became a master of style. Of course, his mastery is due also to his untiring effort to achieve directness and simplicity, to his wide reading which was continually enriching his vocabulary, and to his diligent study of the great writers, not of our language only but of French also, and Latin and Greek.

As a result of his immense experience as a teacher he learned how to put together an address so that it could most easily be apprehended by his hearers. He bestowed upon his lectures a logical structure, which sustained them throughout. He proceeded from the beginning to the middle and from the middle to the end, by regular steps, so that all who listened to him could follow his progress without undue effort. He never "wrote down" to the level of an uneducated audience, but he so deftly prepared his presentation of unfamiliar facts and unexpected conclusions that his uneducated audience had no difficulty in taking in his meaning as he unfolded it. He addressed them not from the remote and austere elevation of the scholar, but familiarly and in friendly fashion, as ordinary men speak to one another when they have matters of importance to communicate.

In his desire to make himself clear, and so to shape what he had to impart that it should be easy to under-

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stand, he was greatly aided by his training as an anatomist, which had taught him the prime importance of the skeleton, with all its bones, each in its proper place, ready to support the muscles and the nerves. He bestowed this buttressed framework on all his addresses and on all his articles; but he always clothed it with flesh and blood, so that it was ever present, although it was never paraded. This is one reason why his lectures and his papers on varied subjects are worthier of detailed study than essays by writers of a more obvious brilliance, who are not infrequently careless of construction and who are occasionally inclined to pay less attention to what they have to say than to the way in which they are going to say it.

This praise of Huxley's style must not be taken to imply that he was a faultless writer, always impeccable in his use of words. Unfortunately this is not the case; and he was not free from petty departures from absolute correctness of usage—more often in his letters than in his lectures, but even in these now and again. He was guilty of using *like* for *as* and of writing (in a letter to Darwin) "*like* the Yankees do." He spoke of "a papyrus which neither Brugsch nor Maspero *have* yet got hold of." He employed the familiar Britic̈ism, *directly* for *as soon as*, i.e., "*directly* I arrived." He said "those kind of people." And he referred to "Men, who like you and *I*, stand." But these slight errors, while they are regrettable, and while they are blemishes on his record as a man of letters, were, after all, only a few. Absolute accuracy in writing is like liberty; it demands eternal vigilance. Huxley's trivial inaccuracies never interfered with the logic of his structure or with the vigor of his statement.

II

No one can read the addresses and essays included in the present volume without recognizing that Huxley was a towering example of a man who had been well educated. Yet when we search his autobiography for information about his schooling we discover to our surprise that he was practically self-taught. He has told us that his "regular school training was of the briefest" and that the teachers in the school he attended cared nothing for the "intellectual and moral welfare" of their pupils. However ill-prepared he might have been, he began the study of medicine when he was only fifteen, not in a well-organized and well-equipped medical school, but as a pupil-assistant to a brother-in-law, who was a practicing physician. When he was only seventeen he won a free scholarship at the Charing Cross Hospital and Medical School; and his application for admission declared that he had a fair knowledge of Latin, read French with facility, and knew something of German. When he was twenty he won a gold medal for anatomy and physiology, and received the degree of Bachelor of Medicine.

How had he acquired his Latin, his French, and his German? How had he trained himself so that he was able to surpass his competitors in his knowledge of anatomy and physiology? "I worked extremely hard when it pleased me," so he states in his early account of his youth, "and when it did not—which was a very frequent case—I was extremely idle. . . . I read everything I could lay hands upon, including novels, and took up all

sorts of pursuits to drop them again quite as speedily." This confession calls for two comments; the first is that Huxley, in his old age, probably underestimated the hard work that he did as a youth and overestimated the idleness indulged in; and the second is that what he termed idleness—that is, abstention from his allotted tasks to devote his time to a wide range of reading, was probably profitable to him in that it opened his eyes to the immense variety of human experience and to the insufficiency of human knowledge. Then at the Charing Cross Hospital he had the great good fortune to come under the influence of a born teacher. Impressed by the extent and precision of this lecturer's knowledge and liking "the severe exactness of his method of lecturing," Huxley worked hard to obtain his approbation.

Thus we see that Huxley had early acquired the habit of hard work; that he was stimulated by an inspiring instructor; and that he was, all unconsciously, fitting himself for his life-work. Then when he was only twenty-one he was appointed an assistant surgeon in the navy and assigned to the *Rattlesnake,* which set sail for the South Seas and on which Huxley was to spend four years in exploration and investigation. In this protracted voyage his habit of hard work, his insatiable curiosity about life, and his indomitable energy worked in combination so effectively that the young fellow who boarded the *Rattlesnake* possessing only the elementary instruction needed by an assistant surgeon, returned to England a thoroughly well-trained naturalist, an acute observer whose awakened imagination enabled him to interpret the result of his laborious observations.

Somehow in those four years of exile he had taught himself how to be independent, how to stand on his own feet, how to do his own thinking, and how to pierce through the skin of a problem to the heart of it. He had discovered that he must never be overawed by authority and that he had a right to inspect the evidence alleged in support of any theory. He had learned to reject all generalization not solidly rooted in the conscientious investigation of every available fact. "If any one tells me, 'it stands to reason' that such things must happen," so he wrote later in life, "I generally find reason to doubt the safety of his standing."

This scientific integrity is exhibited in all his reports on his researches and in all his essays and addresses. And these latter papers reveal a breadth of outlook beyond the borders of science—a largeness of vision due to his retention all his life of his boyhood habit of reading every book he could lay hands on. His son has told us that Huxley "possessed a wonderful faculty for tearing out the heart of a book, reading it through at a gallop, but knowing what it said on all the points that interested him." He grasped at once "the substance of what an author had written; how it fitted into his own scheme of knowledge; and where to find any point again when he wished to cite it." The results of this incessant perusal of all sorts of books in half-a-dozen different languages, modern and ancient—he learned Greek in middle life mainly that he might assure himself as to the exact meaning of a statement of Aristotle's—these results are abundantly evident in Huxley's works. Bacon has told us that "reading maketh a full man, conference a ready man, and writing

an exact man." Huxley was a full man, who was ever ready and always exact.

So it was that by sheer force of character Huxley was able to overcome the disadvantages due to his lack of school training and of university culture. He had given himself the truly liberal education he once defined in an unforgettable paragraph, to be found in one of the addresses in this volume but demanding to be emphasized by quotation here:

"That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of Nature or of art, to hate all vileness, and to respect others as himself."

III

When Huxley paid his only visit to the United States he was greatly attracted by the many tugboats tearing up and down and across the broad waters of the Bay of New

York. "They seemed to him," so his son has recorded, "the condensation and complete expression of the energy and force in which he delighted." And with the fanciful humor, which helped to make him so captivatingly human, he declared, "If I were not a man, I think I should like to be a tug!"

This remark shows that Huxley, amid all the other knowledge he had acquired in half a century of life, knew himself. His essential characteristic was energy, which gave him imagination, enthusiasm, and power. It was his energy which enabled him to give himself a liberal education; and it was his energy again which kept alive his delight in debate. He was an intellectual athlete who joyed in combat with a foeman worthy of his steel. Inmitigably veracious himself, he was disgusted not only with outright falsehood, but perhaps even more by shifty evasion and by ignorant assumption. Holding that "the truth shall set us free," he was bold and prompt in declaring the truth and in attacking error.

In this readiness to defend the right, as he saw it, he felt that he was only doing his duty as a man of science; but he would not have denied that he sprang into the arena the more eagerly because of his keen pleasure in polemic. But this joy in the combat never led him into undue heat or unfair statement. He held himself bound to be courteous always and to present, as far as might be possible, the truth, the whole truth, and nothing but the truth. He refused ever to be an advocate—"if by an advocate is meant one whose business it is to smooth over real difficulties, and to persuade when he cannot convince." Yet he maintained that "among public benefactors, we

reckon him who explodes old error, as next in rank to him who discovers new truth." He declared that in his public addresses he had aimed to stir up his countrymen to think about certain themes of high importance; and then, half-apologetically, he added that the only use of controversy is that it "appeals to their love of fighting, and secures their attention."

Nearly always in his addresses, and not infrequently even in his more leisurely essays, there is a combative tone. This may be explained by the fact that Huxley had two objects in his mind when he was moved to public utterance. One was special to the topic in hand at the moment, a lobster or a piece of chalk or a liberal education; and the other was general and common to all his addresses and essays, since it was an aggressive desire to set forth the claims of science, to insist upon the necessity of increasing our acquaintance with Nature and of enlarging our knowledge of her laws. In pursuit of this more general object, Huxley knew that he was fighting against a deep-rooted intolerance with which he could not very well help being impatient.

It was perhaps partly because of his detestation of this slothful prejudice against the newer discoveries of science, likely to explode established superstitions, which led Huxley to defend Darwin and to lose no opportunity to declare and to emphasize the immense value of Darwin's illuminating explanation of the origin of species. In so doing he shared in the temporary obloquy bestowed upon Darwin, and in time also on Tyndall. They were all three insulted as if they had been criminals; and this is not surprising, since, as Lord Morley said in his book on Vol-

taire, "where it is a duty to worship the sun, it is pretty sure to be a crime to examine the laws of heat."

It is probable that Huxley's frequent incursions into disputed fields, that his willingness to play "the part of something between maid-of-all-work and gladiator-general for science," as he himself phrased it, prevented him from accomplishing as much scientific investigation and of achieving as many scientific discoveries as might have been expected from a man of his extraordinary endowment and equipment. Apparently he was conscious, and not a little regretful, that he had not been able to live out his life in the quiet of his laboratory with his full force expended on pure science. The regret, even if felt acutely, was not bitter; and he was reconciled to the result of his labors.

This, at least, is the testimony of the autobiography, in which he asserts that he had subordinated his ambition for scientific fame to other ends—"to the popularization of science; to the development and organization of scientific education; to the endless series of battles and skirmishes over evolution." This is not the place nor is the present writer the person, to undertake an evaluation of Huxley's own contribution to science; and it must be sufficient to point out that he was acknowledged to be one of the three or four scientific leaders in Great Britain in the second half of the nineteenth century. His fellow workers, those best able to appreciate his merits, elected him to the Royal Society when he was only twenty-six and promoted him to be its president before he was sixty, besides awarding him at different times the Copley, Wollaston, Linnean, and Darwin medals.

IV

It was not without fitness that certain of Huxley's addresses were by him entitled "Lay Sermons." He was not only a man of science and a man of letters, he was also a preacher expounding a doctrine that he believed to be of imperative importance. As has already been pointed out, he himself possessed the enthusiasm for truth and the fanaticism of veracity which he regarded as the most precious of man's possible possessions, because "veracity is the heart of morality."

He held that "moral duty consisted in the observance of those rules of conduct, which contribute to the welfare of society, and (by implication) of the individuals who compose it." His code was not made up of petty precepts and of minor maxims of the utilitarian sort which were laid down by a common sense philosopher like Benjamin Franklin. Although he surely recognized the practical validity of these monitions, Huxley's own morality was loftier in its appeal, broader in its scope, and more difficult of attainment, since it was founded upon a knowledge of the inexorable laws of nature, as these necessarily affected the conduct of man. And on one occasion he made use of the privilege of the preacher to put his meaning in the form of a parable—suggested to him by the famous painting depicting Satan playing chess with a man for his soul. This parable will be found in one of the addresses included in this volume, that on "A Liberal Education"; but, like Huxley's definition of that education, it may be well to set it here at the end of this

introduction, because it contains the core of Huxley's creed, and it explains the reason why he thought it necessary to keep on expounding that creed in lay sermon after lay sermon:

"It is a very plain and elementary truth, that the life, the fortune, and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game, infinitely more difficult and more complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. But also we know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated—without haste but without remorse."

Longfellow once wrote in a notebook that "autobiography is what biography ought to be"; and although the filial piety of Mr. Leonard Huxley has given us the admirable volumes of his father's "Life and Letters," Huxley's outline of his own birth and upbringing and early career has an individuality and a self-revelatory quality which makes it invaluable for a full appreciation of the man himself. Especially does it show us Huxley's own

estimate of himself—an estimate very like that which his friends and contemporaries had arrived at.

It is rather an account of his own evolution than a record of the mere facts of his life; and if we wish to know more about him, about his many activities, about his contributions to science, about his writings, we must look elsewhere. All these things can be found in the ample biography for which we are indebted to his son. In the Appendix to the present volume there is a chronological table, which will enable the student to survey the seventy years of Huxley's life, one after another. This table supplies the dates of publication for all of Huxley's more important writings. It chronicles the posts that he held and the honors that came to him. And in a parallel column attention is called to other happenings of the three score years and ten between 1825 and 1895—years of high importance in the progress of mankind.

Brander Matthews

Columbia University
in the City of New York.

I

AUTOBIOGRAPHY

[This outline sketch of his early life was written in 1889 when Huxley was sixty-four and when he had still six years to live. It omits to record his thirty years' service in various professorships and in important administrative positions. It does not note his voyage to the United States in 1876 nor his visits to the continent and to Egypt. It makes no mention of the failure of his health from overwork, which forced him, in 1885, to surrender his official posts and to leave London and settle in a house of his own at Eastbourne.

Here he interested himself in gardening and in the revision of his scattered writings for a uniform edition. Freedom from care and responsibility helped to improve his health; and in these years of retirement he found strength to write not a few of his most pungent essays. He retained his intellectual energy to the end; and he found life unfailingly interesting. So it was that he attained to the allotted threescore years and ten. He died at Eastbourne on June 29, 1895.]

I

AUTOBIOGRAPHY

AND when I consider, in one view, the many things . . . which I have upon my hands, I feel the burlesque of being employed in this manner at my time of life. But, in another view, and taking in all circumstances, these things, as trifling as they may appear, no less than things of greater importance, seem to be put upon me to do. . . .—*Bishop Butler to the Duchess of Somerset.*

The "many things" to which the Duchess's correspondent here refers are the repairs and improvements of the episcopal seat at Auckland. I doubt if the great apologist, greater in nothing than in the simple dignity of his character, would have considered the writing an account of himself as a thing which could be put upon him to do whatever circumstances might be taken in. But the good bishop lived in an age when a man might write books and yet be permitted to keep his private existence to himself; in the pre-Boswellian epoch, when the germ of the photographer lay in the womb of the distant future, and the interviewer who pervades our

age was an unforeseen, indeed unimaginable, birth of time.

At present, the most convinced believer in the aphorism "Bene qui latuit, bene vixit," is not always able to act up to it. An importunate person informs him that his portrait is about to be published and will be accompanied by a biography which the importunate person proposes to write. The sufferer knows what that means; either he undertakes to revise the "biography" or he does not. In the former case, he makes himself responsible; in the latter, he allows the publication of a mass of more or less fulsome inaccuracies for which he will be held responsible by those who are familiar with the prevalent art of self-advertisement. On the whole, it may be better to get over the "burlesque of being employed in this manner" and do the thing himself.

It was by reflections of this kind that, some years ago, I was led to write and permit the publication of the subjoined sketch.

I was born about eight o'clock in the morning on the 4th of May, 1825, at Ealing, which was, at that time, as quiet a little country village as could be found within half-a-dozen miles of Hyde Park Corner. Now it is a suburb of London with, I believe, 30,000 inhabitants. My father was one of the masters in a large semi-public school which at one time had a high reputation. I am not aware that any portents preceded my arrival in this world, but, in my childhood, I remember hearing a traditional account of the manner in which I lost the chance of an endowment of great practical value. The windows of my mother's room were open, in consequence of the unusual warmth of the weather. For the same reason,

probably, a neighboring beehive had swarmed, and the new colony, pitching on the window-sill, was making its way into the room when the horrified nurse shut down the sash. If that well-meaning woman had only abstained from her ill-timed interference, the swarm might have settled on my lips, and I should have been endowed with that mellifluous eloquence which, in this country, leads far more surely than worth, capacity, or honest work, to the highest places in Church and State. But the opportunity was lost, and I have been obliged to content myself through life with saying what I mean in the plainest of plain language, than which, I suppose, there is no habit more ruinous to a man's prospects of advancement.

Why I was christened Thomas Henry I do not know; but it is a curious chance that my parents should have fixed for my usual denomination upon the name of that particular Apostle with whom I have always felt most sympathy. Physically and mentally I am the son of my mother so completely—even down to peculiar movements of the hands, which made their appearance in me as I reached the age she had when I noticed them—that I can hardly find any trace of my father in myself, except an inborn faculty for drawing, which unfortunately, in my case, has never been cultivated, a hot temper, and that amount of tenacity of purpose which unfriendly observers sometimes call obstinacy.

My mother was a slender brunette, of an emotional and energetic temperament, and possessed of the most piercing black eyes I ever saw in a woman's head. With no more education than other women of the middle classes in her day, she had an excellent mental capacity. Her

most distinguishing characteristic, however, was rapidity of thought. If one ventured to suggest she had not taken much time to arrive at any conclusion, she would say, "I cannot help it, things flash across me." That peculiarity has been passed on to me in full strength; it has often stood me in good stead; it has sometimes played me sad tricks, and it has always been a danger. But, after all, if my time were to come over again, there is nothing I would less willingly part with than my inheritance of mother wit.

I have next to nothing to say about my childhood. In later years my mother, looking at me almost reproachfully, would sometimes say, "Ah! you were such a pretty boy!" whence I had no difficulty in concluding that I had not fulfilled my early promise in the matter of looks. In fact, I have a distinct recollection of certain curls of which I was vain, and of a conviction that I closely resembled that handsome, courtly gentleman, Sir Herbert Oakley, who was vicar of our parish, and who was as a god to us country folk, because he was occasionally visited by the then Prince George of Cambridge. I remember turning my pinafore wrong side forwards in order to represent a surplice, and preaching to my mother's maids in the kitchen as nearly as possible in Sir Herbert's manner one Sunday morning when the rest of the family were at church. That is the earliest indication I can call to mind of the strong clerical affinities which my friend Mr. Herbert Spencer has always ascribed to me, though I fancy they have for the most part remained in a latent state.

My regular school training was of the briefest, perhaps

fortunately, for though my way of life has made me acquainted with all sorts and conditions of men, from the highest to the lowest, I deliberately affirm that the society I fell into at school was the worst I have ever known. We boys were average lads, with much the same inherent capacity for good and evil as any others; but the people who were set over us cared about as much for our intellectual and moral welfare as if they were baby-farmers. We were left to the operation of the struggle for existence among ourselves, and bullying was the least of the ill practices current among us. Almost the only cheerful reminiscence in connection with the place which arises in my mind is that of a battle I had with one of my classmates, who had bullied me until I could stand it no longer. I was a very slight lad, but there was a wild-cat element in me which, when roused, made up for lack of weight, and I licked my adversary effectually. However, one of my first experiences of the extremely rough-and-ready nature of justice, as exhibited by the course of things in general, arose out of the fact that I—the victor—had a black eye, while he—the vanquished—had none, so that I got into disgrace and he did not. We made it up, and thereafter I was unmolested. One of the greatest shocks I ever received in my life was to be told a dozen years afterwards by the groom who brought me my horse in a stable-yard in Sydney that he was my quondam antagonist. He had a long story of family misfortune to account for his position, but at that time it was necessary to deal very cautiously with mysterious strangers in New South Wales, and on inquiry I found that the unfortunate

young man had not only been "sent out," but had undergone more than one colonial conviction.

As I grew older, my great desire was to be a mechanical engineer, but the fates were against this and, while very young, I commenced the study of medicine under a medical brother-in-law. But, though the Institute of Mechanical Engineers would certainly not own me, I am not sure that I have not all along been a sort of mechanical engineer *in partibus infidelium*. I am now occasionally horrified to think how very little I ever knew or cared about medicine as the art of healing. The only part of my professional course which really and deeply interested me was physiology, which is the mechanical engineering of living machines; and, notwithstanding that natural science has been my proper business, I am afraid there is very little of the genuine naturalist in me. I never collected anything, and species work was always a burden to me; what I cared for was the architectural and engineering part of the business, the working out the wonderful unity of plan in the thousands and thousands of diverse living constructions, and the modifications of similar apparatuses to serve diverse ends. The extraordinary attraction I felt towards the study of the intricacies of living structure nearly proved fatal to me at the outset. I was a mere boy—I think between thirteen and fourteen years of age—when I was taken by some older student friends of mine to the first *post-mortem* examination I ever attended. All my life I have been most unfortunately sensitive to the disagreeables which attend anatomical pursuits, but on this occasion my curiosity overpowered all other feelings, and I spent two

or three hours in gratifying it. I did not cut myself, and none of the ordinary symptoms of dissection-poison supervened, but poisoned I was somehow, and I remember sinking into a strange state of apathy. By way of a last chance, I was sent to the care of some good, kind people, friends of my father's, who lived in a farmhouse in the heart of Warwickshire. I remember staggering from my bed to the window on the bright spring morning after my arrival, and throwing open the casement. Life seemed to come back on the wings of the breeze, and to this day the faint odor of wood-smoke, like that which floated across the farm-yard in the early morning, is as good to me as the "sweet south upon a bed of violets." I soon recovered, but for years I suffered from occasional paroxysms of internal pain, and from that time my constant friend, hypochondriacal dyspepsia, commenced his half century of cotenancy of my fleshly tabernacle.

Looking back on my "Lehrjahre," I am sorry to say that I do not think that any account of my doings as a student would tend to edification. In fact, I should distinctly warn ingenuous youth to avoid imitating my example. I worked extremely hard when it pleased me, and when it did not—which was a very frequent case—I was extremely idle (unless making caricatures of one's pastors and masters is to be called a branch of industry), or else wasted my energies in wrong directions. I read everything I could lay hands upon, including novels, and took up all sorts of pursuits to drop them again quite as speedily. No doubt it was very largely my own fault, but the only instruction from which I ever obtained the proper effect of education was that which I received from

Mr. Wharton Jones, who was the lecturer on physiology at the Charing Cross School of Medicine. The extent and precision of his knowledge impressed me greatly, and the severe exactness of his method of lecturing was quite to my taste. I do not know that I have ever felt so much respect for anybody as a teacher before or since. I worked hard to obtain his approbation, and he was extremely kind and helpful to the youngster who, I am afraid, took up more of his time than he had any right to do. It was he who suggested the publication of my first scientific paper—a very little one—in the *Medical Gazette* of 1845, and most kindly corrected the literary faults which abounded in it, short as it was; for at that time, and for many years afterwards, I detested the trouble of writing, and would take no pains over it.

It was in the early spring of 1846, that, having finished my obligatory medical studies and passed the first M.B. examination at the London University—though I was still too young to qualify at the College of Surgeons—I was talking to a fellow-student (the present eminent physician, Sir Joseph Fayrer), and wondering what I should do to meet the imperative necessity for earning my own bread, when my friend suggested that I should write to Sir William Burnett, at that time Director-General for the Medical Service of the Navy, for an appointment. I thought this rather a strong thing to do, as Sir William was personally unknown to me, but my cheery friend would not listen to my scruples, so I went to my lodgings and wrote the best letter I could devise. A few days afterwards I received the usual official circular of acknowledgment, but at the bottom there was

written an instruction to call at Somerset House on such a day. I thought that looked like business, so at the appointed time I called and sent in my card, while I waited in Sir William's ante-room. He was a tall, shrewd-looking old gentleman, with a broad Scotch accent—and I think I see him now as he entered with my card in his hand. The first thing he did was to return it, with the frugal reminder that I should probably find it useful on some other occasion. The second was to ask whether I was an Irishman. I suppose the air of modesty about my appeal must have struck him. I satisfied the Director-General that I was English to the backbone, and he made some inquiries as to my student career, finally desiring me to hold myself ready for examination. Having passed this, I was in Her Majesty's Service, and entered on the books of Nelson's old ship, the *Victory,* for duty at Haslar Hospital, about a couple of months after I made my application.

My official chief at Haslar was a very remarkable person, the late Sir John Richardson, an excellent naturalist, and far-famed as an indomitable Arctic traveler. He was a silent, reserved man, outside the circle of his family and intimates; and, having a full share of youthful vanity, I was extremely disgusted to find that "Old John," as we irreverent youngsters called him, took not the slightest notice of my worshipful self either the first time I attended him, as it was my duty to do, or for some weeks afterwards. I am afraid to think of the lengths to which my tongue may have run on the subject of the churlishness of the chief, who was, in truth, one of the kindest-hearted and most considerate of men.

But one day, as I was crossing the hospital square, Sir John stopped me, and heaped coals of fire on my head by telling me that he had tried to get me one of the resident appointments, much coveted by the assistant surgeons, but that the Admiralty had put in another man. "However," said he, "I mean to keep you here till I can get you something you will like," and turned upon his heel without waiting for the thanks I stammered out. That explained how it was I had not been packed off to the West Coast of Africa like some of my juniors, and why, eventually, I remained altogether seven months at Haslar.

After a long interval, during which "Old John" ignored my existence almost as completely as before, he stopped me again as we met in a casual way, and describing the service on which the *Rattlesnake* was likely to be employed, said that Captain Owen Stanley, who was to command the ship, had asked him to recommend an assistant surgeon who knew something of science; would I like that? Of course I jumped at the offer. "Very well, I give you leave; go to London at once and see Captain Stanley." I went, saw my future commander, who was very civil to me, and promised to ask that I should be appointed to his ship, as in due time I was. It is a singular thing that, during the few months of my stay at Haslar, I had among my messmates two future Directors-General of the Medical Service of the Navy (Sir Alexander Armstrong and Sir John Watt-Reid), with the present President of the College of Physicians and my kindest of doctors, Sir Andrew Clark.

Life on board Her Majesty's ships in those days was

a very different affair from what it is now, and ours was exceptionally rough, as we were often many months without receiving letters or seeing any civilized people but ourselves. In exchange, we had the interest of being about the last voyagers, I suppose, to whom it could be possible to meet with people who knew nothing of fire-arms—as we did on the south Coast of New Guinea—and of making acquaintance with a variety of interesting savage and semi-civilized people. But, apart from experience of this kind and the opportunities offered for scientific work, to me, personally, the cruise was extremely valuable. It was good for me to live under sharp discipline; to be down on the realities of existence by living on bare necessaries; to find out how extremely well worth living life seemed to be when one woke up from a night's rest on a soft plank, with the sky for canopy and coco and weevilly biscuit the sole prospect for breakfast; and, more especially, to learn to work for the sake of what I got for myself out of it, even if it all went to the bottom and I along with it. My brother officers were as good fellows as sailors ought to be and generally are, but, naturally, they neither knew nor cared anything about my pursuits, nor understood why I should be so zealous in pursuit of the objects which my friends, the middies, christened "Buffons," after the title conspicuous on a volume of the "Suits à Buffon," which stood on my shelf in the chart room.

During the four years of our absence, I sent home communication after communication to the "Linnean Society," with the same result as that obtained by Noah when he sent the raven out of his ark. Tired at last of hearing

nothing about them, I determined to do or die, and in 1849 I drew up a more elaborate paper and forwarded it to the Royal Society. This was my dove, if I had only known it. But owing to the movements of the ship, I heard nothing of that either until my return to England in the latter end of the year 1850, when I found that it was printed and published, and that a huge packet of separate copies awaited me. When I hear some of my young friends complain of want of sympathy and encouragement, I am inclined to think that my naval life was not the least valuable part of my education.

Three years after my return were occupied by a battle between my scientific friends on the one hand and the Admiralty on the other, as to whether the latter ought, or ought not, to act up to the spirit of a pledge they had given to encourage officers who had done scientific work by contributing to the expense of publishing mine. At last the Admiralty, getting tired, I suppose, cut short the discussion by ordering me to join a ship, which thing I declined to do, and as Rastignac, in the Père Goriot, says to Paris, I said to London *"à nous deux."* I desired to obtain a Professorship of either Physiology or Comparative Anatomy, and as vacancies occurred I applied, but in vain. My friend, Professor Tyndall, and I were candidates at the same time, he for the Chair of Physics and I for that of Natural History in the University of Toronto, which, fortunately, as it turned out, would not look at either of us. I say fortunately, not from any lack of respect for Toronto, but because I soon made up my mind that London was the place for me, and hence I have steadily declined the inducements to leave it, which have at

various times been offered. At last, in 1854, on the translation of my warm friend Edward Forbes, to Edinburgh, Sir Henry de la Beche, the Director-General of the Geological Survey, offered me the post Forbes vacated of Paleontologist and Lecturer on Natural History. I refused the former point blank, and accepted the latter only provisionally, telling Sir Henry that I did not care for fossils, and that I should give up Natural History as soon as I could get a physiological post. But I held the office for thirty-one years, and a large part of my work has been paleontological.

At that time I disliked public speaking, and had a firm conviction that I should break down every time I opened my mouth. I believe I had every fault a speaker could have (except talking at random or indulging in rhetoric), when I spoke to the first important audience I ever addressed, on a Friday evening at the Royal Institution, in 1852. Yet, I must confess to having been guilty, *malgré moi,* of as much public speaking as most of my contemporaries, and for the last ten years it ceased to be so much of a bugbear to me. I used to pity myself for having to go through this training, but I am now more disposed to compassionate the unfortunate audiences, especially my ever-friendly hearers at the Royal Institution, who were the subjects of my oratorical experiments.

The last thing that it would be proper for me to do would be to speak of the work of my life, or to say at the end of the day whether I think I have earned my wages or not. Men are said to be partial judges of themselves. Young men may be, I doubt if old men are. Life seems terribly foreshortened as they look back, and

the mountain they set themselves to climb in youth turns out to be a mere spur of immeasurably higher ranges when, with failing breath, they reach the top. But if I may speak of the objects I have had more or less definitely in view since I began the ascent of my hillock, they are briefly these: To promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life to the best of my ability, in the conviction which has grown with my growth and stengthened with my strength, that there is no alleviation for the sufferings of mankind except veracity of thought and of action, and the resolute facing of the world as it is when the garment of make-believe by which pious hands have hidden its uglier features is stripped off.

It is with this intent that I have subordinated any reasonable, or unreasonable, ambition for scientific fame which I may have permitted myself to entertain to other ends; to the popularization of science; to the development and organization of scientific education; to the endless series of battles and skirmishes over evolution; and to untiring opposition to that ecclesiastical spirit, that clericalism, which in England, as everywhere else, and to whatever denomination it may belong, is the deadly enemy of science.

In striving for the attainment of these objects, I have been but one among many, and I shall be well content to be remembered, or even not remembered, as such. Circumstances, among which I am proud to reckon the devoted kindness of many friends, have led to my occupation of various prominent positions, among which the

Presidency of the Royal Society is the highest. It would be mock modesty on my part, with these and other scientific honors which have been bestowed upon me, to pretend that I have not succeeded in the career which I have followed, rather because I was driven into it than of my own free will; but I am afraid I should not count even these things as marks of success if I could not hope that I had somewhat helped that movement of opinion which has been called the New Reformation.

II

ON THE METHOD OF ZADIG

[This lecture was delivered at the Working Men's College in 1880. It is included in the present volumes for several reasons. First, because it is an admirable specimen of Huxley's clear thinking, careful construction, and apt phrasing. Secondly, because it brings out the identity of the methods of science and of the judgments of common sense, supporting Huxley's earlier assertion that "Science is nothing but trained and organized common sense." And thirdly, because the Zadig of Voltaire is an elder brother of the two most famous detectives in modern literature, the Monsieur Dupin of Edgar Allan Poe (in the "Murders in the Rue Morgue") and the Sherlock Holmes of Sir Arthur Conan Doyle. Zadig has the sharp eyes and the habit of observation which enables him to see the significance of things apparently insignificant; and he has the trained and organized common sense which supplies him with the power to interpret the meaning of the facts he has perceived.

The method of Zadig is the method of Monsieur Dupin and of Sherlock Holmes; and Huxley shows that it is also and necessarily the method by means of which the man of science solves puzzles seemingly as inexplicable as those mastered by the heroes of the detective story. It is

also the method of Natty Bumppo and of his Indian enemies (in the "Leatherstocking Tales" of Fenimore Cooper) whereby they are equipped to follow the trail of a foe in the seemingly trackless forest. And Huxley takes pleasure in making plain to us that the method of the men of the backwoods and of the detectives of our story-books is also the method of Cuvier when he reconstructed the skeleton of an extinct animal from a single tooth or a single fragment of bone. It is with pride in the certainty of this application of "trained and organized common sense" that Huxley ended his address by a pregnant prediction that it will in no very distant future enable science "to reconstruct the scheme of life from its beginning."]

II

ON THE METHOD OF ZADIG

[1880]

RETROSPECTIVE PROPHECY AS A FUNCTION OF SCIENCE

'Une marque plus sure que toutes celles de Zadig."
—CUVIER.*

IT is an usual and a commendable practice to preface the discussion of the views of a philosophic thinker by some account of the man and of the circumstances which shaped his life and colored his way of looking at things; but, though Zadig is cited in one of the most important chapters of Cuvier's greatest work, little is known about him, and that little might perhaps be better authenticated than it is.

It is said that he lived at Babylon in the time of King Moabdar; but the name of Moabdar does not appear in the list of Babylonian sovereigns brought to light by the patience and the industry of the decipherers of cuneiform inscriptions in these later years; nor indeed am I aware

* "Discours sur les revolutions de la surface du globe." Recherches sur les Ossemens Fossiles, Ed. iv T. i. p. 185.

that there is any other authority for his existence than that of the biographer of Zadig, one Arouet de Voltaire, among whose more conspicuous merits strict historical accuracy is perhaps hardly to be reckoned.

Happily Zadig is in the position of a great many other philosophers. What he was like when he was in the flesh, indeed whether he existed at all, are matters of no great consequence. What we care about in a light is that it shows the way, not whether it is lamp or candle, tallow or wax. Our only real interest in Zadig lies in the conceptions of which he is the putative father; and his biographer has stated these with so much clearness and vivacious illustration, that we need hardly feel a pang, even if critical research should prove King Moabdar and all the rest of the story to be unhistorical, and reduce Zadig himself to the shadowy condition of a solar myth.

Voltaire tells us that, disenchanted with life by sundry domestic misadventures, Zadig withdrew from the turmoil of Babylon to a secluded retreat on the banks of the Euphrates, where he beguiled his solitude by the study of nature. The manifold wonders of the world of life had a particular attraction for the lonely student; incessant and patient observation of the plants and animals about him sharpened his naturally good powers of observation and of reasoning; until, at length, he acquired a sagacity which enabled him to perceive endless minute differences among objects which, to the untutored eye, appeared absolutely alike.

It might have been expected that this enlargement of the powers of the mind and of its store of natural knowledge could tend to nothing but the increase of a man's

own welfare and the good of his fellow-man. But Zadig was fated to experience the vanity of such expectations.

"One day, walking near a little wood, he saw, hastening that way, one of the Queen's chief eunuchs, followed by a troop of officials, who appeared to be in the greatest anxiety, running hither and thither like men distraught, in search of some lost treasure.

"'Young man,' cried the eunuch, 'have you seen the Queen's dog?' Zadig answered modestly, 'A very small spaniel; she limps with the left foreleg, and has very long ears.' 'Ah you! have seen her then,' said the breathless eunuch. 'No,' answered Zadig, 'I have not seen her; and I really was not aware that the Queen possessed a spaniel.'

"By an odd coincidence, at the very same time, the handsomest horse in the King's stables broke away from his groom in the Babylonian plain. The grand huntsman and all his staff were seeking the horse with as much anxiety as the eunuch and his people the spaniel; and the grand huntsman asked Zadig if he had not seen the King's horse go that way.

"'A first-rate galloper, small-hoofed, five feet high; tail three feet and a half long; cheek pieces of the bit of twenty-three carat gold; shoes silver?' said Zadig.

"'Which way did he go? Where is he?' cried the grand huntsman.

"'I have not seen anything of the horse, and I never heard of him before,' replied Zadig.

"The grand huntsman and the chief eunuch made sure that Zadig had stolen both the King's horse and the Queen's spaniel, so they haled him before the High Court of Desterham, which at once condemned him to the knout, and transportation for life to Siberia. But the sentence was hardly pronounced when the lost horse and spaniel were found. So the judges were under the painful necessity of reconsidering their decision; but they fined Zadig four hundred ounces of gold for saying he had seen that which he had not seen.

"The first thing was to pay the fine; afterwards Zadig was permitted to open his defense to the court, which he did in the following terms:

" 'Stars of justice, abysses of knowledge, mirrors of truth, whose gravity is as that of lead, whose inflexibility is as that of iron, who rival the diamond in clearness, and possess no little affinity with gold; since I am permitted to address your august assembly, I swear by Ormuzd that I have never seen the respectable lady dog of the Queen, nor beheld the sacrosanct horse of the King of Kings.

" 'This is what happened. I was taking a walk towards the little wood near which I subsequently had the honor to meet the venerable chief eunuch and the most illustrious grand huntsman. I noticed the track of an animal in the sand, and it was easy to see that it was that of a small dog. Scrapings of the sand, which always lay close to the marks of the forepaws, indicated that she had very long ears; and, as the imprint of one foot was always fainter than

those of the other three, I judged that the dog of our august Queen was, if I may venture to say so, a little lame.

" 'With respect to the horse of the King of Kings, permit me to observe that, wandering through the paths which traverse the wood, I noticed the marks of horse-shoes. They were all equidistant. "Ah!" said I, "this is a famous galloper." In a narrow valley, only seven feet wide, the dust upon the trunks of the trees was a little disturbed at three feet and a half from the middle of the path. "This horse," said I to myself, "had a tail three feet and a half long, and, lashing it from one side to the other, he has swept away the dust." Branches of the trees met overhead at the height of five feet, and under them I saw newly fallen leaves; so I knew that the horse had brushed some of the branches, and was therefore five feet high. As to his bit, it must have been made of twenty-three carat gold, for he had rubbed it against a stone, which turned out to be a touchstone, with the properties of which I am familiar by experiment. Lastly, by the marks which his shoes left upon pebbles of another kind, I was led to think that his shoes were of fine silver.'

"All the judges admired Zadig's profound and subtle discernment; and the fame of it reached even the King and the Queen. From the ante-rooms to the presence-chamber, Zadig's name was in everybody's mouth; and, although many of the magi were of opinion that he ought to be burnt as a sorcerer, the King commanded that the four hundred ounces of

> gold which he had been fined should be restored to him. So the officers of the court went in state with the four hundred ounces; only they retained three hundred and ninety-eight for legal expenses, and their servants expected fees."

Those who are interested in learning more of the fateful history of Zadig must turn to the original; we are dealing with him only as a philosopher, and this brief excerpt suffices for the exemplification of the nature of his conclusion and of the methods by which he arrived at them.

These conclusions may be said to be of the nature of retrospective prophecies; though it is perhaps a little hazardous to employ phraseology which perilously suggests a contradiction in terms—the word "prophecy" being so constantly, in ordinary use, restricted to "foretelling." Strictly, however, the term prophecy applies as much to outspeaking as to foretelling; and, even in the restricted sense of "divination," it is obvious that the essence of the prophetic operation does not lie in its backward or forward relation to the course of time, but in the fact that it is the apprehension of that which lies out of the sphere of immediate knowledge; the seeing of that which, to the natural sense of the seer, is invisible.

The foreteller asserts that, at some future time, a properly situated observer will witness certain events; the clairvoyant declares that, at this present time, certain things are to be witnessed a thousand miles away; the retrospective prophet (would that there were such a word as "backteller!") affirms that, so many hours or

years ago, such and such things were to be seen. In all these cases, it is only the relation to time which alters—the process of divination beyond the limits of possible direct knowledge remains the same.

No doubt it was their instinctive recognition of the analogy between Zadig's results and those obtained by authorized inspiration which inspired the Babylonian magi with the desire to burn the philosopher. Zadig admitted that he had never either seen or heard of the horse of the king or of the spaniel of the queen; and yet he ventured to assert in the most positive manner that animals answering to their description did actually exist and ran about the plains of Babylon. If this method was good for the divination of the course of events ten hours old, why should it not be good for those of ten years or ten centuries past; nay, might it not extend ten thousand years and justify the impious in meddling with the traditions of Oannes and the fish, and all the sacred foundations of Babylonian cosmogony?

But this was not the worst. There was another consideration which obviously dictated to the more thoughtful of the magi the propriety of burning Zadig out of hand. His defense was worse than his offense. It showed that his mode of divination was fraught with danger to magianism in general. Swollen with the pride of human reason, he had ignored the established canons of magian lore; and, trusting to what, after all, was mere carnal common sense, he professed to lead men to a deeper insight into nature than magian wisdom, with all its lofty antagonism to everything common, had ever reached. What, in fact, lay at the foundation of all

Zadig's arguments but the coarse commonplace assumption, upon which every act of our daily lives is based, that we may conclude from an effect to the pre-existence of a cause competent to produce that effect?

The tracks were exactly like those which dogs and horses leave; therefore they were the effects of such animals as causes. The marks at the sides of the fore-prints of the dog track were exactly such as would be produced by long trailing ears; therefore the dog's long ears were the causes of these marks—and so on. Nothing can be more hopelessly vulgar, more unlike the majestic development of a system of grandly unintelligible conclusions from sublimely inconceivable premises such as delights the magian heart. In fact, Zadig's method was nothing but the method of all mankind. Retrospective prophecies, far more astonishing for their minute accuracy than those of Zadig, are familiar to those who have watched the daily life of nomadic people.

From freshly broken twigs, crushed leaves, disturbed pebbles, and imprints hardly discernible by the untrained eye, such graduates in the University of Nature will divine, not only the fact that a party has passed that way, but its strength, its composition, the course it took, and the number of hours or days which have elapsed since it passed. But they are able to do this because, like Zadig, they perceive endless minute differences where untrained eyes discern nothing; and because the unconscious logic of common sense compels them to account for these effects by the causes which they know to be competent to produce them.

And such mere methodized savagery was to discover

the hidden things of nature better than *a priori* deductions from the nature of Ormuzd—perhaps to give a history of the past, in which Oannes would be altogether ignored. Decidedly it were better to burn this man at once.

If instinct, or an unwonted use of reason, led Moabdar's magi to this conclusion two or three thousand years ago, all that can be said is that subsequent history has fully justified them. For the rigorous application of Zadig's logic to the results of accurate and long-continued observation has founded all those sciences which have been termed historical or paleontological, because they are retrospectively prophetic and strive towards the reconstruction in human imagination of events which have vanished and ceased to be.

History, in the ordinary acceptation of the word, is based upon the interpretation of documentary evidence; and documents would have no evidential value unless historians were justified in their assumption that they have come into existence by the operation of causes similar to those of which documents are, in our present experience, the effects. If a written history can be produced otherwise than by human agency, or if the man who wrote a given document was actuated by other than ordinary human motives, such documents are of no more evidential value than so many arabesques.

Archeology, which takes up the thread of history beyond the point at which documentary evidence fails us, could have no existence, except for our well grounded confidence that monuments and works of art or artifice, have never been produced by causes different in kind

from those to which they now owe their origin. And geology, which traces back the course of history beyond the limits of archeology, could tell us nothing except for the assumption that, millions of years ago, water, heat, gravitation, friction, animal and vegetable life, caused effects of the same kind as they now cause. Nay, even physical astronomy, in so far as it takes us back to the uttermost point of time which paleontological science can reach, is founded upon the same assumption. If the law of gravitation ever failed to be true, even to a small extent, for that period, the calculations of the astronomer have no application.

The power of prediction, of prospective prophecy, is that which is commonly regarded as the great prerogative of physical science. And truly it is a wonderful fact that one can go into a shop and buy for a small price a book, the "Nautical Almanac," which will foretell the exact position to be occupied by one of Jupiter's moons six months hence; nay, more, that, if it were worth while, the Astronomer-Royal could furnish us with as infallible a prediction applicable to 1980 or 2980.

But astronomy is not less remarkable for its power of retrospective prophecy.

Thales, oldest of Greek philosophers, the dates of whose birth and death are uncertain, but who flourished about 600 B. C., is said to have foretold an eclipse of the sun which took place in his time during a battle between the Medes and the Lydians. Sir George Airy has written a very learned and interesting memoir* in

* "On the Eclipses of Agathocles, Thales, and Xerxes," Philosophical Transactions, vol. cxiii.

which he proves that such an eclipse was visible in Lydia on the afternoon of the 28th of May in the year 585 B. C.

No one doubts that, on the day and at the hour mentioned by the Astronomer-Royal, the people of Lydia saw the face of the sun totally obscured. But, though we implicitly believe this retrospective prophecy, it is incapable of verification. In the total absence of historical records, it is impossible even to conceive any means of ascertaining directly whether the eclipse of Thales happened or not. All that can be said is, that the prospective prophecies of the astronomer are always verified; and that, inasmuch as his retrospective prophecies are the result of following backwards the very same method as that which invariably leads to verified results, when it is worked forwards, there is as much reason for placing full confidence in the one as in the other. Retrospective prophecy is therefore a legitimate function of astronomical science; and if it is legitimate for one science it is legitimate for all; the fundamental axiom on which it rests, the constancy of the order of nature, being the common foundation of all scientific thought. Indeed, if there can be grades in legitimacy, certain branches of science have the advantage over astronomy, in so far as their retrospective prophecies are not only susceptible of verification, but are sometimes strikingly verified.

Such a science exists in that application of the principles of biology to the interpretation of the animal and vegetable remains imbedded in the rocks which compose the surface of the globe, which is called Paleontology.

At no very distant time, the question whether these so-called "fossils" were really the remains of animals

and plants was hotly disputed. Very learned persons maintained that they were nothing of the kind, but a sort of concretion, or crystallization, which had taken place within the stone in which they are found, and which simulated the forms of animal and vegetable life, just as frost on a window-pane imitates vegetation. At the present day, it would probably be impossible to find any sane advocate of this opinion; and the fact is rather surprising, that among the people from whom the circle-squarers, perpetual-motioners, flat-earthed men and the like, are recruited, to say nothing of table-turners and spirit-rappers, somebody has not perceived the easy avenue to nonsensical notoriety open to any one who will take up the good old doctrine, that fossils are all *lusus naturæ*.

The position would be impregnable, inasmuch as it is quite impossible to prove the contrary. If a man choose to maintain that a fossil oyster shell, in spite of its correspondence, down to every minutest particular, with that of an oyster fresh taken out of the sea, was never tenanted by a living oyster, but is a mineral concretion, there is no demonstrating his error. All that can be done is to show him that, by a parity of reasoning, he is bound to admit that a heap of oyster shells outside a fishmonger's door may also be "sports of nature," and that a mutton bone in a dust-bin may have had the like origin. And when you cannot prove that people are wrong, but only that they are absurd, the best course is to let them alone.

The whole fabric of paleontology, in fact, falls to the ground unless we admit the validity of Zadig's great

principle, that like effects imply like causes, and the process of reasoning from a shell, or a tooth, or a bone, to the nature of the animal to which it belonged, rests absolutely on the assumption that the likeness of this shell, or tooth, or bone, to that of some animal with which we are already acquainted, is such that we are justified in inferring a corresponding degree of likeness in the rest of the two organisms. It is on this very simple principle, and not upon imaginary laws of physiological correlation, about which, in most cases, we know nothing whatever, that the so-called restorations of the paleontologist are based.

Abundant illustrations of this truth will occur to every one who is familiar with paleontology; none is more suitable than the case of the so-called *Belemnites*. In the early days of the study of fossils, this name was given to certain elongated stony bodies, ending at one extremity in a conical point, and truncated at the other, which were commonly reputed to be thunderbolts, and as such to have descended from the sky. They are common enough in some parts of England; and, in the condition in which they are ordinarily found, it might be difficult to give satisfactory reasons for denying them to be merely mineral bodies.

They appear, in fact, to consist of nothing but concentric layers of carbonate of lime, disposed in subcrystalline fibers, or prisms, perpendicular to the layers. Among a great number of specimens of these Belemnites, however, it was soon observed that some showed a conical cavity at the blunt end; and, in still better preserved specimens, this cavity appeared to be divided into

chambers by delicate saucer-shaped partitions, situated at regular intervals, one above the other. Now there is no mineral body which presents any structure comparable to this, and the conclusion suggested itself that the Belemnites must be the effects of causes other than those which are at work in inorganic nature. On close examination, the saucer-shaped partitions were proved to be all perforated at one point, and the perforations being situated exactly in the same line, the chambers were seen to be traversed by a canal, or *siphuncle,* which thus connected the smallest or apical chamber with the largest. There is nothing like this in the vegetable world; but an exactly corresponding structure is met with in the shells of two kinds of existing animals, the pearly *Nautilus* and the *Spirula,* and only in them. These animals belong to the same division—the *Cephalopoda*—as the cuttle-fish, the squid, and the octopus. But they are the only existing members of the group which possess chambered, siphunculated shells; and it is utterly impossible to trace any physiological connection between the very peculiar structural characters of a cephalopod and the presence of a chambered shell. In fact, the squid has, instead of any such shell, a horny "pen," the cuttle-fish has the so-called "cuttlebone," and the octopus has no shell, or, at most, a mere rudiment of one.

Nevertheless, seeing that there is nothing in nature at all like the chambered shell of the Belemnite, except the shells of the *Nautilus* and of the *Spirula,* it was legitimate to prophesy that the animal from which the fossil proceeded must have belonged to the group of the *Cephalopoda. Nautilus* and *Spirula* are both very rare

animals, but the progress of investigation brought to light the singular fact, that, though each has the characteristic cephalopodous organization, it is very different from the other. The shell of *Nautilus* is external, that of *Spirula* internal; *Nautilus* has four gills, *Spirula* two; *Nautilus* has multitudinous tentacles, *Spirula* has only ten arms beset with horny-rimmed suckers; *Spirula,* like the squids and cuttle-fishes, which it closely resembles, has a bag of ink which it squirts out to cover its retreat when alarmed; *Nautilus* has none.

No amount of physiological reasoning could enable any one to say whether the animal which fabricated the Belemnite was more like *Nautilus,* or more like *Spirula.* But the accidental discovery of Belemnites in due connection with black elongated masses which were certainly fossilized ink-bags, inasmuch as the ink could be ground up and used for painting as well as if it were recent sepia, settled the question; and it became perfectly safe to prophesy that the creature which fabricated the Belemnite was a two-gilled cephalopod with suckers on its arms, and with all the other essential features of our living squids, cuttle-fishes, and *Spirulæ.* The paleontologist was, by this time, able to speak as confidently about the animal of the Belemnite, as Zadig was respecting the queen's spaniel. He could give a very fair description of its external appearance, and even enter pretty fully into the details of its internal organization, and yet could declare that neither he, nor any one else, had ever seen one. And as the queen's spaniel was found, so happily has the animal of the Belemnite; a few exceptionally preserved specimens having been discovered, which com-

pletely verify the retrospective prophecy of those who interpreted the facts of the case by due application of the method of Zadig.

These Belemnites flourished in prodigious abundance in the seas of the Mesozoic, or secondary, age of the world's geological history; but no trace of them has been found in any of the tertiary deposits, and they appear to have died out towards the close of the Mesozoic epoch. The method of Zadig, therefore, applies in full force to the events of a period which is immeasurably remote, which long preceded the origin of the most conspicuous mountain masses of the present world, and the deposition, at the bottom of the ocean, of the rocks which form the greater part of the soil of our present continents. The Euphrates itself, at the mouth of which Oannes landed, is a thing of yesterday compared with a Belemnite; and even the liberal chronology of magian cosmogony fixes the beginning of the world only at a time when other applications of Zadig's method afford convincing evidence that, could we have been there to see, things would have looked very much as they do now. Truly the magi were wise in their generation; they foresaw rightly that this pestilent application of the principles of common sense, inaugurated by Zadig, would be their ruin.

But it may be said that the method of Zadig, which is simple reasoning from analogy, does not account for the most striking feats of modern paleontology—the reconstruction of entire animals from a tooth or perhaps a fragment of a bone; and it may be justly urged that Cuvier, the great master of this kind of investigation,

gave a very different account of the process which yielded such remarkable results.

Cuvier is not the first man of ability who has failed to make his own mental processes clear to himself, and he will not be the last. The matter can be easily tested. Search the eight volumes of the "Recherches sur les Ossemens Fossiles" from cover to cover, and nothing but the application of the method of Zadig will be found in the arguments by which a fragment of a skeleton is made to reveal the characters of the animal to which it belonged.

There is one well-known case which may represent all. It is an excellent illustration of Cuvier's sagacity, and he evidently takes some pride in telling his story about it. A split slab of stone arrived from the quarries of Montmartre, the two halves of which contained the greater part of the skeleton of a small animal. On careful examinations of the characters of the teeth and of the lower jaw, which happened to be exposed, Cuvier assured himself that they presented such a very close resemblance to the corresponding parts in the living opossums that he at once assigned the fossil to that genus.

Now the opossums are unlike most mammals in that they possess two bones attached to the fore part of the pelvis, which are commonly called "marsupial bones." The name is a misnomer, originally conferred because it was thought that these bones have something to do with the support of the pouch, or marsupium, with which some, but not all, of the opossums are provided. As a matter of fact, they have nothing to do with the support of the pouch, and they exist as much in those opossums

which have no pouches as in those which possess them. In truth, no one knows what the use of these bones may be, nor has any valid theory of their physiological import yet been suggested. And if we have no knowledge of the physiological importance of the bones themselves, it is obviously absurd to pretend that we are able to give physiological reasons why the presence of these bones is associated with certain peculiarities of the teeth and of the jaws. If any one knows why four molar teeth and an inflected angle of the jaw are very generally found along with marsupial bones, he has not yet communicated that knowledge to the world.

If, however, Zadig was right in concluding from the likeness of the hoof-prints which he observed to be a horse's that the creature which made them had a tail like that of a horse, Cuvier, seeing that the teeth and jaw of his fossil were just like those of an opossum, had the same right to conclude that the pelvis would also be like an opossum's; and so strong was his conviction that this retrospective prophecy, about an animal which he had never seen before, and which had been dead and buried for millions of years would be verified, that he went to work upon the slab which contained the pelvis in confident expectation of finding and laying bare the "marsupial bones," to the satisfaction of some persons whom he had invited to witness their disinterment. As he says:—"Cette opération se fit en présence de quelques personnes à qui j'en avais annoncé d'avance le résultat, dans l'intention de leur prouver par le fait la justice de nos théories zoölogiques; puisque le vrai cachet d'une

théorie est sans contredit la faculté qu'elle donne de prévoir les phénomènes."

In the "Ossemens Fossiles" Cuvier leaves his paper just as it first appeared in the "Annales du Muséum," as "a curious monument of the force of zoölogical laws and of the use which may be made of them."

Zoölogical laws truly, but not physiological laws. If one sees a live dog's head, it is extremely probable that a dog's tail is not far off, though nobody can say why that sort of head and that sort of tail go together; what physiological connection there is between the two. So, in the case of the Montmartre fossil, Cuvier, finding a thorough opossum's head, concluded that the pelvis also would be like an opossum's. But, most assuredly, the most advanced physiologist of the present day could throw no light on the question why these are associated, nor could pretend to affirm that the existence of the one is necessarily connected with that of the other. In fact, had it so happened that the pelvis of the fossil had been originally exposed, while the head lay hidden, the presence of the "marsupial bones," though very like an opossum's, would by no means have warranted the prediction that the skull would turn out to be that of the opossum. It might just as well have been like that of some other marsupial; or even like that of the totally different group of Monotremes, of which the only living representatives are the *Echidna* and the *Ornithorhynchus*.

For all practical purposes, however, the empirical laws of co-ordination of structures, which are embodied in the generalizations of morphology, may be confidently trusted, if employed with due caution, to lead to a just

interpretation of fossil remains; or, in other words, we may look for the verification of the retrospective prophecies which are based upon them.

And if this be the case, the late advances which have been made in paleontological discovery open out a new field for such prophecies. For it has been ascertained with respect to many groups of animals that, as we trace them back in time, their ancestors gradually cease to exhibit those special modifications which at present characterize the type, and more nearly embody the general plan of the group to which they belong.

Thus, in the well-known case of the horse, the toes which are suppressed in the living horse are found to be more and more complete in the older members of the group, until, at the bottom of the Tertiary series of America, we find an equine animal which has four toes in front and three behind. No remains of the horse tribe are at present known from any Mesozoic deposit. Yet who can doubt that, whenever a sufficiently extensive series of lacustrine and fluviatile beds of that age becomes known, the lineage which has been traced thus far will be continued by equine quadrupeds with an increasing number of digits, until the horse type merges in the five-toed form towards which these gradations point?

But the argument which holds good for the horse, holds good, not only for all mammals, but for the whole animal world. And as the study of the pedigrees, or lines of evolution, to which, at present, we have access, brings to light, as it assuredly will do, the laws of that process, we shall be able to reason from the facts with which the geological record furnishes us to those which have

hitherto remained, and many of which, perhaps, may forever remain, hidden. The same method of reasoning which enables us, when furnished with a fragment of an extinct animal, to prophesy the character which the whole organism exhibited, will, sooner or later, enable us, when we know a few of the later terms of a genealogical series, to predict the nature of the earlier terms.

In no very distant future, the method of Zadig, applied to a greater body of facts than the present generation is fortunate enough to handle, will enable the biologist to reconstruct the scheme of life from its beginning, and to speak as confidently of the character of long extinct living beings, no trace of which has been preserved, as Zadig did of the queen's spaniel and the king's horse. Let us hope that they may be better rewarded for their toil and their sagacity than was the Babylonian philosopher; for perhaps, by that time, the magi also may be reckoned among the members of a forgotten Fauna, extinguished in the struggle for existence against their great rival, common sense.

III

A LOBSTER

[This lecture was delivered at the South Kensington Museum in 1861; and it was intended especially for teachers. It is the earliest of Huxley's addresses to popular audiences; and it was delivered when he was not yet thirty years of age. It is an exemplification of the result of the method of Zadig, when this is applied by a man of science who is also a man of letters, who possesses "trained and organized common sense" and also the interpreting imagination which enabled him to arrive at the truth from out of a chaos of mere facts.

It is an alluring introduction to the study of Zoölogy, just as the later and companion lecture "On a Piece of Chalk" is an equally alluring introduction to the study of Geology. It reveals Huxley's early mastery of the art of exposition. It displays his ability to give a carefully articulated skeleton to what is seemingly only a simple talk on a simple subject. It is logically put together with a central theme always kept in mind and continually supported by a variety of illuminating illustrations.]

III

A LOBSTER

OR THE STUDY OF ZOÖLOGY

[1861]

Natural History is the name familiarly applied to the study of the properties of such natural bodies as minerals, plants, and animals; the sciences which embody the knowledge man has acquired upon these subjects are commonly termed Natural Sciences, in contradistinction to other so-called "physical" sciences; and those who devote themselves especially to the pursuit of such sciences have been and are commonly termed "Naturalists."

Linnæus was a naturalist in this wide sense, and his "Systema Naturæ" was a work upon natural history, in the broadest acceptation of the term; in it, that great methodizing spirit embodied all that was known in his time of the distinctive characters of minerals, animals, and plants. But the enormous stimulus which Linnæus gave to the investigation of nature soon rendered it impossible that any one man should write another "Systema Naturæ," and extremely difficult for any one to become even a naturalist such as Linnæus was.

Great as have been the advances made by all the three

branches of science of old, included under the title of natural history, there can be no doubt that zoölogy and botany have grown in an enormously greater ratio than mineralogy; and hence, as I suppose, the name of "natural history" has gradually become more and more definitely attached to these prominent divisions of the subject, and by "naturalist" people have meant more and more distinctly to imply a student of the structure and function of living beings.

However this may be, it is certain that the advance of knowledge has gradually widened the distance between mineralogy and its old associates, while it has drawn zoölogy and botany closer together; so that of late years it has been found convenient (and indeed necessary) to associate the sciences which deal with vitality and all its phenomena under the common head of "biology"; and the biologists have come to repudiate any blood-relationship with their foster-brothers, the mineralogists.

Certain broad laws have a general application throughout both the animal and the vegetable worlds, but the ground common to these kingdoms of nature is not of very wide extent, and the multiplicity of details is so great, that the student of living beings finds himself obliged to devote his attention exclusively either to the one or the other. If he elects to study plants, under any aspect, we know at once what to call him. He is a botanist, and his science is botany. But if the investigation of animal life be his choice, the name generally applied to him will vary according to the kind of animals he studies, or the particular phenomena of animal life to which he confines his attention. If the study of man

is his object, he is called an anatomist, or a physiologist, or an ethnologist; but if he dissects animals, or examines into the mode in which their functions are performed, he is a comparative anatomist or comparative physiologist. If he turns his attention to fossil animals, he is a paleontologist. If his mind is more particularly directed to the specific description, discrimination, classification, and the distribution of animals, he is termed a zoölogist.

For the purpose of the present discourse, however, I shall recognize none of these titles save the last, which I shall employ as the equivalent of botanist, and I shall use the term zoölogy as denoting the whole doctrine of animal life, in contradistinction to botany, which signifies the whole doctrine of vegetable life.

Employed in this sense, zoölogy, like botany, is divisible into three great but subordinate sciences, morphology, physiology, and distribution, each of which may, to a very great extent, be studied independently of the other.

Zoölogical morphology is the doctrine of animal form or structure. Anatomy is one of its branches; development is another; while classification is the expression of the relations which different animals bear to one another, in respect of their anatomy and their development.

Zoölogical distribution is the study of animals in relation to the terrestrial conditions which obtain now, or have obtained at any previous epoch of the earth's history.

Zoölogical physiology, lastly, is the doctrine of the functions or actions of animals. It regards animal bodies as machines impelled by certain forces, and performing an amount of work which can be expressed in terms of the ordinary forces of nature. The final object of physiology

is to deduce the facts of morphology on the one hand, and those of distribution on the other, from the laws of the molecular forces of matter.

Such is the scope of zoölogy. But if I were to content myself with the enunciation of these dry definitions, I should ill exemplify that method of teaching this branch of physical science which it is my chief business to-night to recommend. Let us turn away then from abstract definitions. Let us take some concrete living thing, some animal, the commoner the better, and let us see how the application of common sense and common logic to the obvious facts it presents, inevitably leads us into all these branches of zoölogical science.

I have before me a lobster. When I examine it, what appears to be the most striking character it presents? Why, I observe that this part which we call the tail of the lobster, is made up of six distinct hard rings and a seventh terminal piece. If I separate one of the middle rings, say the third, I find it carries upon its under surface a pair of limbs or appendages, each of which consists of a stalk and two terminal pieces. So that I can represent a transverse section of the ring and its appendages upon the diagram board in this way.

If I now take the fourth ring, I find it has the same structure, and so have the fifth and the second; so that, in each of these divisions of the tail, I find parts which correspond with one another, a ring and two appendages; and in each appendage a stalk and two end pieces. These corresponding parts are called, in the technical language of anatomy, "homologous parts." The ring of the third division is the "homologue" of the ring of the fifth, the

appendage of the former is the homologue of the appendage of the latter. And, as each division exhibits corresponding parts in corresponding places, we say that all the divisions are constructed upon the same plan. But now let us consider the sixth division. It is similar to, and yet different from, the others. The ring is essentially the same as in the other divisions; but the appendages look at first as if they were very different; and yet when we regard them closely, what do we find? A stalk and two terminal divisions, exactly as in the others, but the stalk is very short and very thick, the terminal divisions are very broad and flat, and one of them is divided into two pieces.

I may say, therefore, that the sixth segment is like the others in plan, but that it is modified in its details.

The first segment is like the others, so far as its ring is concerned, and though its appendages differ from any of those yet examined in the simplicity of their structure, parts corresponding with the stem and one of the divisions of the appendages of the other segments can be readily discerned in them.

Thus it appears that the lobster's tail is composed of a series of segments which are fundamentally similar, though each presents peculiar modifications of the plan common to all. But when I turn to the forepart of the body I see, at first, nothing but a great shield-like shell, called technically the "carapace," ending in front in a sharp spine, on either side of which are the curious compound eyes, set upon the ends of stout movable stalks. Behind these, on the under side of the body, are two pairs of long feelers, or antennæ, followed by six pairs of

jaws folded against one another over the mouth, and five pairs of legs, the foremost of these being the great pinchers, or claws, of the lobster.

It looks, at first, a little hopeless to attempt to find in this complex mass a series of rings, each with its pair of appendages, such as I have shown you in the abdomen, and yet it is not difficult to demonstrate their existence. Strip off the legs, and you will find that each pair is attached to a very definite segment of the under wall of the body; but these segments, instead of being the lower part of free rings, as in the tail, are such parts of rings which are all solidly united and bound together; and the like is true of the jaws, the feelers, and the eye-stalks, every pair of which is borne upon its own special segment. Thus the conclusion is gradually forced upon us, that the body of the lobster is composed of as many rings as there are pairs of appendages, namely, twenty in all, but that the six hindmost rings remain free and movable, while the fourteen front rings become firmly soldered together, their backs forming one continuous shield—the carapace.

Unity of plan, diversity in execution, is the lesson taught by the study of the rings of the body, and the same instruction is given still more emphatically by the appendages. If I examine the outermost jaw I find it consists of three distinct portions, an inner, a middle, and an outer, mounted upon a common stem; and if I compare this jaw with the legs behind it, or the jaws in front of it, I find it quite easy to see, that, in the legs, it is the part of the appendage which corresponds with the inner division, which becomes modified into what we know

familiarly as the "leg," while the middle division disappears, and the outer division is hidden under the carapace. Nor is it more difficult to discern that, in the appendages of the tail, the middle division appears again and the outer vanishes; while, on the other hand, in the foremost jaw, the so-called mandible, the inner division only is left; and, in the same way, the parts of the feelers and of the eye-stalks can be identified with those of the legs and jaws.

But whither does all this tend? To the very remarkable conclusion that a unity of plan, of the same kind as that discoverable in the tail or abdomen of the lobster, pervades the whole organization of its skeleton, so that I can return to the diagram representing any one of the rings of the tail, which I drew upon the board, and by adding a third division to each appendage, I can use it as a sort of scheme or plan of any ring of the body. I can give names to all the parts of that figure, and then if I take any segment of the body of the lobster, I can point out to you exactly what modification the general plan has undergone in that particular segment; what part has remained movable, and what has become fixed to another; what has been excessively developed and metamorphosed and what has been suppressed.

But I imagine I hear the question, How is all this to be tested? No doubt it is a pretty and ingenious way of looking at the structure of any animal; but is it anything more? Does Nature acknowledge, in any deeper way, this unity of plan we seem to trace?

The objection suggested by these questions is a very valid and important one, and morphology was in an

unsound state so long as it rested upon the mere perception of the analogies which obtain between fully formed parts. The unchecked ingenuity of speculative anatomists proved itself fully competent to spin any number of contradictory hypotheses out of the same facts, and endless morphological dreams threatened to supplant scientific theory.

Happily, however, there is a criterion of morphological truth, and a sure test of all homologies. Our lobster has not always been what we see it; it was once an egg, a semi-fluid mass of yolk, not so big as a pin's head, contained in a transparent membrane, and exhibiting not the least trace of any one of those organs, the multiplicity and complexity of which, in the adult, are so surprising. After a time, a delicate patch of cellular membrane appeared upon one face of this yolk, and that patch was the foundation of the whole creature, the clay out of which it would be molded. Gradually investing the yolk, it became subdivided by transverse constrictions into segments, the forerunners of the rings of the body. Upon the ventral surface of each of the rings thus sketched out, a pair of bud-like prominences made their appearance—the rudiments of the appendages of the ring. At first, all the appendages were alike, but, as they grew, most of them became distinguished into a stem and two terminal divisions, to which, in the middle part of the body, was added a third outer division; and it was only at a later period, that by the modification, or absorption, of certain of these primitive constituents, the limbs acquired their perfect form.

Thus the study of development proves that the doc-

trine of unity of plan is not merely a fancy, that it is not merely one way of looking at the matter, but that it is the expression of deep-seated natural facts. The legs and jaws of the lobster may not merely be regarded as modifications of a common type—in fact and in nature they are so—the leg and the jaw of the young animal being, at first, indistinguishable.

These are wonderful truths, the more so because the zoölogist finds them to be of universal application. The investigation of a polype, of a snail, of a fish, of a horse, or of a man, would have led us, though by a less easy path, perhaps, to exactly the same point. Unity of plan everywhere lies hidden under the mask of diversity of structure—the complex is everywhere evolved out of the simple. Every animal has at first the form of an egg, and every animal and every organic part, in reaching its adult state, passes through conditions common to other animals and other adult parts; and this leads me to another point. I have hitherto spoken as if the lobster were alone in the world, but, as I need hardly remind you, there are myriads of other animal organisms. Of these, some, such as men, horses, birds, fishes, snails, slugs, oysters, corals, and sponges, are not in the least like the lobster. But other animals, though they may differ a good deal from the lobster, are yet either very like it, or are like something that is like it. The crayfish, the rock lobster, the prawn, and the shrimp, for example, however different, are yet so like lobsters that a child would group them as of the lobster kind, in contradistinction to snails and slugs; and these last again would form

a kind by themselves, in contradistinction to cows, horses, and sheep, the cattle kind.

But this spontaneous grouping into "kinds" is the first essay of the human mind at classification, or the calling by a common name of those things that are alike, and the arranging them in such a manner as best to suggest the sum of their likenesses and unlikenesses to other things.

Those kinds which include no other subdivisions than the sexes, or various breeds, are called, in technical language, species. The English lobster is a species, our crayfish is another, our prawn is another. In other countries, however, there are lobsters, crayfish, and prawns, very like ours, and yet presenting sufficient differences to deserve distinction. Naturalists, therefore, express this resemblance and this diversity by grouping them as distinct species of the same "genus." But the lobster and the crayfish, though belonging to distinct genera, have many features in common, and hence are grouped together in an assemblage which is called a family. More distant resemblances connect the lobster with the prawn and the crab, which are expressed by putting all these into the same order. Again, more remote, but still very definite, resemblances unite the lobster with the woodlouse, the king crab, the water flea, and the barnacle, and separate them from all other animals; whence they collectively constitute the larger group, or class, *Crustacea*. But the *Crustacea* exhibit many peculiar features in common with insects, spiders, and centipedes, so that these are grouped into the still larger assemblage or "province" *Articulata;* and, finally, the

relations which these have to worms and other lower animals, are expressed by combining the whole vast aggregate into the sub-kingdom of *Annulosa.*

If I had worked my way from a sponge instead of a lobster, I should have found it associated, by like ties, with a great number of other animals into the sub-kingdom *Protozoa;* if I had selected a fresh-water polype or a coral, the members of what naturalists term the sub-kingdom *Cœlenterata* would have grouped themselves around my type; had a snail been chosen, the inhabitants of all univalve and bivalve, land and water, shells, the lamp shells, the squids, and the sea-mat would have gradually linked themselves on to it as members of the same sub-kingdom of *Mollusca;* and finally, starting from man, I should have been compelled to admit first, the ape, the rat, the horse, the dog, into the same class; and then the bird, the crocodile, the turtle, the frog, and the fish, into the same sub-kingdom of *Vertebrata.*

And if I had followed out all these various lines of classification fully, I should discover in the end that there was no animal, either recent or fossil, which did not at once fall into one or other of these sub-kingdoms. In other words, every animal is organized upon one or other of the five, or more, plans, the existence of which renders our classification possible. And so definitely and precisely marked is the structure of each animal that, in the present state of our knowledge, there is not the least evidence to prove that a form, in the slightest degree transitional between any of the two groups *Vertebrata, Annulosa, Mollusca,* and *Cœlenterata,* either exists, or has existed, during that period of the earth's history

which is recorded by the geologist.* Nevertheless, you must not for a moment suppose, because no such transitional forms are known, that the members of the subkingdoms are disconnected from, or independent of, one another. On the contrary, in their earliest condition they are all similar, and the primordial germs of a man, a dog, a bird, a fish, a beetle, a snail, and a polype are, in no essential structural respects, distinguishable.

In this broad sense, it may with truth be said that all living animals, and all those dead faunæ which geology reveals, are bound together by an all-pervading unity of organization, of the same character, though not equal in degree, to that which enables us to discern one and the same plan amidst the twenty different segments of a lobster's body. Truly it has been said, that to a clear eye the smallest fact is a window through which the Infinite may be seen.

Turning from these purely morphological considerations, let us now examine into the manner in which the attentive study of the lobster impels us into other lines of research.

Lobsters are found in all the European seas; but on the opposite shores of the Atlantic and in the seas of the southern hemisphere they do not exist. They are, however, represented in these regions by very closely allied but distinct forms—the *Homarus Americanus* and the *Homarus Capensis,* so that we may say that the European has one species of *Homarus;* the American, another; the

* The different grouping necessitated by later knowledge does not affect the principle of the argument.—1894.

African, another; and thus the remarkable facts of geographical distribution begin to dawn upon us.

Again, if we examine the contents of the earth's crust, we shall find in the latter of those deposits, which have served as the great burying grounds of past ages, numberless lobster-like animals, but none so similar to our living lobster as to make zoölogists sure that they belonged even to the same genus. If we go still further back in time, we discover, in the oldest rocks of all, the remains of animals, constructed on the same general plan as the lobster, and belonging to the same great group of *Crustacea;* but for the most part totally different from the lobster, and indeed from any other living form of crustacean; and thus we gain a notion of that successive change of the animal population of the globe, in past ages, which is the most striking fact revealed by geology.

Consider now where our inquiries have led us. We studied our type morphologically when we determined its anatomy and its development, and when comparing it, in these respects, with other animals, we made out its place in a system of classification. If we were to examine every animal in a similar manner, we should establish a complete body of zoölogical morphology.

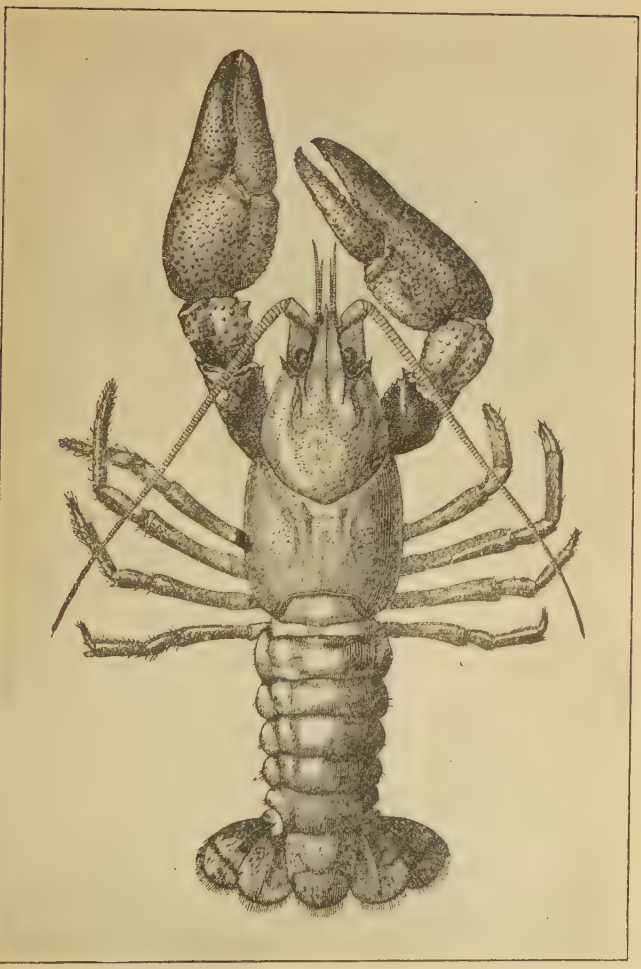
Again, we investigated the distribution of our type in space and in time, and, if the like had been done with every animal, the sciences of geographical and geological distribution would have attained their limit.

But you will observe one remarkable circumstance, that, up to this point, the question of the life of these organisms has not come under consideration. Morphology and distribution might be studied almost as well, if animals

and plants were a peculiar kind of crystals, and possessed none of those functions which distinguish living beings so remarkably. But the facts of morphology and distribution have to be accounted for, and the science, the aim of which it is to account for them, is Physiology.

Let us return to our lobster once more. If we watched the creature in its native element, we should see it climbing actively the submerged rocks, among which it delights to live, by means of its strong legs; or swimming by powerful strokes of its great tail, the appendages of the sixth joint of which are spread out into a broad fan-like propeller: seize it, and it will show you that its great claws are no mean weapons of offense; suspend a piece of carrion among its haunts, and it will greedily devour it, tearing and crushing the flesh by means of its multitudinous jaws.

Suppose that we had known nothing of the lobster but as an inert mass, an organic crystal, if I may use the phrase, and that we could suddenly see it exerting all these powers, what wonderful new ideas and new questions would arise in our minds! The great new question would be, "How does all this take place?" The chief new idea would be, the idea of adaptation to purpose—the notion, that the constituents of animal bodies are not mere unconnected parts, but organs working together to an end. Let us consider the tail of the lobster again from this point of view. Morphology has taught us that it is a series of segments composed of homologous parts, which undergo various modifications—beneath and through which a common plan of formation is discernible. But if I look at the same part physiologically, I see that it is



THE COMMON LOBSTER

a most beautifully constructed organ of locomotion, by means of which the animal can swiftly propel itself either backwards or forwards.

But how is this remarkable propulsive machine made to perform its functions? If I were suddenly to kill one of these animals and to take out all the soft parts, I should find the shell to be perfectly inert, to have no more power of moving itself than is possessed by the machinery of a mill when disconnected from its steam-engine or water-wheel. But if I were to open it, and take out the viscera only, leaving the white flesh, I should perceive that the lobster could bend and extend its tail as well as before. If I were to cut off the tail, I should cease to find any spontaneous motion in it; but on pinching any portion of the flesh, I should observe that it underwent a very curious change—each fiber becoming shorter and thicker. By this act of contraction, as it is termed, the parts to which the ends of the fiber are attached are, of course, approximated; and according to the relations of their points of attachment to the centers of motions of the different rings, the bending or the extension of the tail results. Close observation of the newly opened lobster would soon show that all its movements are due to the same cause—the shortening and thickening of these fleshy fibers, which are technically called muscles.

Here, then, is a capital fact. The movements of the lobster are due to muscular contractility. But why does a muscle contract at one time and not at another? Why does one whole group of muscles contract when the lobster wishes to extend his tail, and another group when he

desires to bend it? What is it originates, directs, and controls the motive power?

Experiment, the great instrument for the ascertainment of truth in physical science, answers this question for us. In the head of the lobster there lies a small mass of that peculiar tissue which is known as nervous substance. Cords of similar matter connect this brain of the lobster, directly or indirectly, with the muscles. Now, if these communicating cords are cut, the brain remaining entire, the power of exerting what we call voluntary motion in the parts below the section is destroyed; and, on the other hand, if, the cords remaining entire, the brain mass be destroyed, the same voluntary mobility is equally lost. Whence the inevitable conclusion is, that the power of originating these motions resides in the brain and is propagated along the nervous cords.

In the higher animals the phenomena which attend this transmission have been investigated, and the exertion of the peculiar energy which resides in the nerves has been found to be accompanied by a disturbance of the electrical state of their molecules.

If we could exactly estimate the signification of this disturbance; if we could obtain the value of a given exertion of nerve force by determining the quantity of electricity, or of heat, of which it is the equivalent; if we could ascertain upon what arrangement, or other condition of the molecules of matter, the manifestation of the nervous and muscular energies depends (and doubtless science will some day or other ascertain these points), physiologists would have attained their ultimate goal in this direction; they would have determined the relation of

the motive force of animals to the other forms of force found in nature; and if the same process had been successfully performed for all the operations which are carried on in, and by, the animal frame, physiology would be perfect, and the facts of morphology and distribution would be deducible from the laws which physiologists had established, combined with those determining the condition of the surrounding universe.

There is not a fragment of the organism of this humble animal whose study would not lead us into regions of thought as large as those which I have briefly opened up to you; but what I have been saying, I trust, has not only enabled you to form a conception of the scope and purport of zoölogy, but has given you an imperfect example of the manner in which, in my opinion, that science, or indeed any physical science, may be best taught. The great matter is, to make teaching real and practical, by fixing the attention of the student on particular facts; but at the same time it should be rendered broad and comprehensive, by constant reference to the generalizations of which all particular facts are illustrations. The lobster has served as a type of the whole animal kingdom, and its anatomy and physiology have illustrated for us some of the greatest truths of biology. The student who has once seen for himself the facts which I have described, has had their relations explained to him, and has clearly comprehended them, has, so far, a knowledge of zoölogy, which is real and genuine, however limited it may be, and which is worth more than all the mere reading knowledge of the science he could ever acquire. His

zoölogical information is, so far, knowledge and not mere hearsay.

And if it were my business to fit you for the certificate in zoölogical science granted by this department, I should pursue a course precisely similar in principle to that which I have taken to-night. I should select a fresh-water sponge, a fresh-water polype or a *Cyanœa*, a fresh-water mussel, a lobster, a fowl, as types of the five primary divisions of the animal kingdom. I should explain their structure very fully, and show how each illustrated the great principles of zoölogy. Having gone very carefully and fully over this ground, I should feel that you had a safe foundation, and I should then take you in the same way, but less minutely, over similarly selected illustrative types of the classes; and then I should direct your attention to the special forms enumerated under the head of types, in this syllabus, and to the other facts there mentioned.

That would, speaking generally, be my plan. But I have undertaken to explain to you the best mode of acquiring and communicating a knowledge of zoölogy, and you may therefore fairly ask me for a more detailed and precise account of the manner in which I should propose to furnish you with the information I refer to.

My own impression is, that the best model for all kinds of training in physical science is that afforded by the method of teaching anatomy, in use in the medical schools. This method consists of three elements—lectures, demonstrations, and examinations.

The object of lectures is, in the first place, to awaken the attention and excite the enthusiasm of the student;

and this, I am sure, may be effected to a far greater extent by the oral discourse and by the personal influence of a respected teacher than in any other way. Secondly, lectures have the double use of guiding the student to the salient points of a subject, and at the same time forcing him to attend to the whole of it, and not merely to that part which takes his fancy. And lastly, lectures afford the student the opportunity of seeking explanations of those difficulties which will, and indeed ought to, arise in the course of his studies.

What books shall I read? is a question constantly put by the student to the teacher. My reply usually is, "None: write your notes out carefully and fully; strive to understand them thoroughly; come to me for the explanation of anything you cannot understand; and I would rather you did not distract your mind by reading." A properly composed course of lectures ought to contain fully as much matter as a student can assimilate in the time occupied by its delivery; and the teacher should always recollect that his business is to feed, and not to cram the intellect. Indeed, I believe that a student who gains from a course of lectures the simple habit of concentrating his attention upon a definitely limited series of facts, until they are thoroughly mastered, has made a step of immeasurable importance.

But, however good lectures may be, and however extensive the course of reading by which they are followed up, they are but accessories to the great instrument of scientific teaching—demonstration. If I insist unweariedly, nay fanatically, upon the importance of physical science as an educational agent, it is because the study of

any branch of science, if properly conducted, appears to me to fill up a void left by all other means of education. I have the greatest respect and love for literature; nothing would grieve me more than to see literary training other than a very prominent branch of education: indeed, I wish that real literary discipline were far more attended to than it is; but I cannot shut my eyes to the fact that there is a vast difference between men who have had a purely literary and those who have had a sound scientific training.

Seeking for the cause of this difference, I imagine I can find it in the fact that, in the world of letters, learning and knowledge are one, and books are the source of both; whereas in science, as in life, learning and knowledge are distinct, and the study of things, and not of books, is the source of the latter.

All that literature has to bestow may be obtained by reading and by practical exercise in writing and in speaking; but I do not exaggerate when I say, that none of the best gifts of science are to be won by these means. On the contrary, the great benefit which a scientific education bestows, whether as training or as knowledge, is dependent upon the extent to which the mind of the student is brought into immediate contact with facts—upon the degree to which he learns the habit of appealing directly to Nature, and of acquiring through his senses concrete images of those properties of things which are, and always will be, but approximately expressed in human language. Our way of looking at Nature, and of speaking about her, varies from year to year; but a fact once seen, a relation of cause and effect once demonstratively apprehended, are

possessions which neither change nor pass away, but, on the contrary, form fixed centers, about which other truths aggregate by natural affinity.

Therefore, the great business of the scientific teacher is to imprint the fundamental, irrefragable facts of his science, not only by words upon the mind, but by sensible impressions upon the eye, and ear, and touch of the student, in so complete a manner that every term used, or law enunciated, should afterwards call up vivid images of the particular structural, or other, facts which furnished the demonstration of the law, or the illustration of the term.

Now this important operation can only be achieved by constant demonstration, which may take place to a certain imperfect extent during a lecture, but which ought also to be carried on independently, and which should be addressed to each individual student, the teacher endeavoring, not so much to show a thing to the learner, as to make him see it for himself.

I am well aware that there are great practical difficulties in the way of effectual zoölogical demonstrations. The dissection of animals is not altogether pleasant, and requires much time; nor is it easy to secure an adequate supply of the needful specimens. The botanist has here a great advantage; his specimens are easily obtained, are clean and wholesome, and can be dissected in a private house as well as anywhere else; and hence, I believe, the fact that botany is so much more readily and better taught than its sister science. But, be it difficult or be it easy, if zoölogical science is to be properly studied, demonstration, and, consequently, dissection, must be had. With-

out it, no man can have a really sound knowledge of animal organization.

A good deal may be done, however, without actual dissection on the student's part, by demonstration upon specimens and preparations; and in all probability it would not be very difficult, were the demand sufficient, to organize collections of such objects, sufficient for all the purposes of elementary teaching, at a comparatively cheap rate. Even without these, much might be effected, if the zoölogical collections, which are open to the public, were arranged according to what has been termed the "typical principle"; that is to say, if the specimens exposed to public view were so selected that the public could learn something from them, instead of being, as at present, merely confused by their multiplicity. For example, the grand ornithological gallery at the British Museum contains between two and three thousand species of birds, and sometimes five or six specimens of a species. They are very pretty to look at, and some of the cases are, indeed, splendid; but I will undertake to say, that no man but a professed ornithologist has ever gathered much information from the collection. Certainly, no one of the tens of thousands of the general public who have walked through that gallery ever knew more about the essential peculiarities of birds when he left the gallery than when he entered it. But if, somewhere in that vast hall, there were a few preparations, exemplifying the leading structural peculiarities and the mode of development of a common fowl; if the types of the genera, the leading modifications in the skeleton, in the plumage at various ages, in the mode of nidification, and the like, among

birds, were displayed; and if the other specimens were put away in a place where the men of science, to whom they are alone useful, could have free access to them, I can conceive that this collection might become a great instrument of scientific education.

The last implement of the teacher to which I have adverted is examination—a means of education now so thoroughly understood that I need hardly enlarge upon it. I hold that both written and oral examinations are indispensable, and, by requiring the description of specimens, they may be made to supplement demonstration.

Such is the fullest reply the time at my disposal will allow me to give to the question—how may a knowledge of zoölogy be best acquired and communicated?

But there is a previous question which may be moved, and which, in fact, I know many are inclined to move. It is the question, why should teachers be encouraged to acquire a knowledge of this, or any other branch of physical science? What is the use, it is said, of attempting to make physical science a branch of primary education? Is it not probable that teachers, in pursuing such studies, will be led astray from the acquirement of more important but less attractive knowledge? And, even if they can learn something of science without prejudice to their usefulness, what is the good of their attempting to instill that knowledge into boys whose real business is the acquisition of reading, writing, and arithmetic?

These questions are, and will be, very commonly asked, for they arise from that profound ignorance of the value and true position of physical science, which infests the minds of the most highly educated and intelligent classes

of the community. But if I did not feel well assured that they are capable of being easily and satisfactorily answered; that they have been answered over and over again; and that the time will come when men of liberal education will blush to raise such questions—I should be ashamed of my position here to-night. Without doubt, it is your great and very important function to carry out elementary education; without question, anything that should interfere with the faithful fulfillment of that duty on your part would be a great evil; and if I thought that your acquirement of the elements of physical science, and your communication of those elements to your pupils, involved any sort of interference with your proper duties, I should be the first person to protest against your being encouraged to do anything of the kind.

But is it true that the acquisition of such a knowledge of science as is proposed, and the communication of that knowledge, are calculated to weaken your usefulness? Or may I not rather ask, is it possible for you to discharge your functions properly without these aids?

What is the purpose of primary intellectual education? I apprehend that its first object is to train the young in the use of those tools wherewith men extract knowledge from the ever-shifting succession of phenomena which pass before their eyes; and that its second object is to inform them of the fundamental laws which have been found by experience to govern the course of things, so that they may not be turned out into the world naked, defenseless, and a prey to the events they might control.

A boy is taught to read his own and other languages in order that he may have access to infinitely wider stores

of knowledge than could ever be opened to him by oral intercourse with his fellow men; he learns to write, that his means of communication with the rest of mankind may be indefinitely enlarged, and that he may record and store up the knowledge he acquires. He is taught elementary mathematics, that he may understand all those relations of number and form upon which the transactions of men, associated in complicated societies, are built, and that he may have some practice in deductive reasoning.

All these operations of reading, writing, and ciphering are intellectual tools, whose use should, before all things, be learned, and learned thoroughly; so that the youth may be enabled to make his life that which it ought to be, a continual progress in learning and in wisdom.

But, in addition, primary education endeavors to fit a boy out with a certain equipment of positive knowledge. He is taught the great laws of morality; the religion of his sect; so much history and geography as will tell him where the great countries of the world are, what they are, and how they have become what they are.

Without doubt all these are most fitting and excellent things to teach a boy; I should be very sorry to omit any of them from any scheme of primary intellectual education. The system is excellent, so far as it goes.

But if I regard it closely, a curious reflection arises. I suppose that, fifteen hundred years ago, the child of any well-to-do Roman citizen was taught just these same things; reading and writing in his own, and, perhaps, the Greek tongue; the elements of mathematics; and the religion, morality, history, and geography current in his

time. Furthermore, I do not think I err in affirming that if such a Christian Roman boy, who had finished his education, could be transplanted into one of our public schools, and pass through its course of instruction, he would not meet with a single unfamiliar line of thought; amidst all the new facts he would have to learn, not one would suggest a different mode of regarding the universe from that current in his own time.

And yet surely there is some great difference between the civilization of the fourth century and that of the nineteenth, and still more between the intellectual habits and tone of thought of that day and this?

And what has made this difference? I answer fearlessly—the prodigious development of physical science within the last two centuries.

Modern civilization rests upon physical science; take away her gifts to our own country, and our position among the leading nations of the world is gone to-morrow; for it is physical science only that makes intelligence and moral energy stronger than brute force.

The whole of modern thought is steeped in science; it has made its way into the works of our best poets, and even the mere man of letters, who affects to ignore and despise science, is unconsciously impregnated with her spirit, and indebted for his best products to her methods. I believe that the greatest intellectual revolution mankind has yet seen is now slowly taking place by her agency. She is teaching the world that the ultimate court of appeal is observation and experiment, and not authority; she is teaching it to estimate the value of evidence; she is creating a firm and living faith in the existence of im-

mutable moral and physical laws, perfect obedience to which is the highest possible aim of an intelligent being.

But of all this your old stereotyped system of education takes no note. Physical science, its methods, its problems, and its difficulties, will meet the poorest boy at every turn, and yet we educate him in such a manner that he shall enter the world as ignorant of the existence of the methods and facts of science as the day he was born. The modern world is full of artillery; and we turn out our children to do battle in it, equipped with the shield and sword of an ancient gladiator.

Posterity will cry shame on us if we do not remedy this deplorable state of things. Nay, if we live twenty years longer, our own consciences will cry shame on us.

It is my firm conviction that the only way to remedy it is to make the elements of physical science an integral part of primary education. I have endeavored to show you how that may be done for that branch of science which it is my business to pursue; and I can but add, that I should look upon the day when every schoolmaster throughout this land was a center of genuine, however rudimentary, scientific knowledge, as an epoch in the history of the country.

But let me entreat you to remember my last words. Addressing myself to you, as teachers, I would say, mere book learning in physical science is a sham and a delusion—what you teach, unless you wish to be impostors, that you must first know; and real knowledge in science means personal acquaintance with the facts, be they few or many.*

* It has been suggested to me that these words may be taken

to imply a discouragement on my part of any sort of scientific instruction which does not give an acquaintance with the facts at first hand. But this is not my meaning. The ideal of scientific teaching is, no doubt, a system by which the scholar sees every fact for himself, and the teacher supplies only the explanations. Circumstances, however, do not often allow of the attainment of that ideal, and we must put up with the next best system—one in which the scholar takes a good deal on trust from a teacher, who, knowing the facts by his own knowledge, can describe them with so much vividness as to enable his audience to form competent ideas concerning them. The system which I repudiate is that which allows teachers who have not come into direct contact with the leading facts of a science to pass their second-hand information on. The scientific virus, like vaccine lymph, if passed through too long a succession of organisms, will lose all its effect in protecting the young against the intellectual epidemics to which they are exposed.

[The remarks on p. 90 applied to the Natural History Collection of the British Museum in 1861. The visitor to the Natural History Museum in 1894 need go no further than the Great Hall to see the realization of my hopes by the present Director.]

IV

ON A PIECE OF CHALK

[This address was delivered to working men in Norwich in 1868, during the meeting of the British Association for the Advancement of Science. It is perhaps an even better instance of Huxley's success in so presenting a message of modern science that it could be apprehended unhesitatingly even by the uneducated, than is his earlier talk on "A Lobster." His son and biographer calls it a perfect example of the handling of a common and trivial subject so as to make it "a window into the infinite."

And his son is not overstating the merits of this lecture when he suggests that it marks "the maturing of his style into that mastery of clear expression for which he deliberately labored, the saying exactly what he meant, neither too much nor too little, without confusion and without obscurity." Have something to say, and say it, was the Duke of Wellington's theory of style; Huxley's was "to say that which has to be said in such language that you can stand cross-examination on each word." He sought to be clear; and he was able to attain the desired lucidity only by so organizing his material that it could be presented in orderly fashion, with a beginning, a middle, and an end, to be instantly perceived by all his hearers.]

IV

ON A PIECE OF CHALK

[1868]

If a well were sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as "chalk."

Not only here, but over the whole county of Norfolk, the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and, on the sea-coast, where the waves have pared away the face of the land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward, the chalk may be followed as far as Yorkshire; on the south coast it appears abruptly in the picturesque western bays of Dorset, and breaks into the Needles of the Isle of Wight; while on the shores of Kent it supplies that long line of white cliffs to which England owes her name of Albion.

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader, and there narrower, might be followed diagonally across England from Lulworth in Dorset to Flamborough Head in York-

shire—a distance of over 280 miles as the crow flies. From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent and Sussex, it enters into the very foundation of all the southeastern counties.

Attaining, as it does in some places, a thickness of more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, much of which has the same general characters as ours, and is found in detached patches, some less, and others more, extensive, than the English. Chalk occurs in northwest Ireland; it stretches over a large part of France—the chalk which underlies Paris being, in fact, a continuation of that of the London basin; it runs through Denmark and Central Europe, and extends southward to North Africa; while eastward, it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia. If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3,000 miles in long diameter—the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs and rounded coombs, covered with

sweet-grassed turf, of our inland chalk country, have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And, in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

What is this widespread component of the surface of the earth, and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification. If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history of man can be supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of the history of the globe, which I hope to enable you to read with your own eyes to-night. Let me add, that few chapters of human history have a more pro-

found significance for ourselves. I weigh my words well when I assert that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature.

The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we "burn" chalk the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas and lime, and when you make it very hot the carbonic acid flies away and the lime is left. By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in bubbles; the lime dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of "carbonate of lime."

It is desirable for us to start from the knowledge of

this fact, though it may not seem to help us very far towards what we seek. For carbonate of lime is a widely spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which have drained through limestone rocks, in the form of what are called stalagmites and stalactites, is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a teakettle is carbonate of lime, and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it—until it is thin enough, in fact, to be examined with any magnifying power that may be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But a slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but imbedded in this matrix are innumerable bodies, some smaller and some larger, but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure. A cubic inch of some specimens of chalk may contain hundreds of thousands

of these bodies, compacted together with incalculable millions of the granules.

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are arranged, and of their relative proportions. But, by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly grown raspberry, being formed of a number of nearly globular chambers of different sizes congregated together. It is called *Globigerina,* and some specimens of chalk consist of little else than *Globigerinæ* and granules. Let us fix our attention upon the *Globigerina.* It is the spoor of the game we are tracking. If we can learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is, that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage—proving that the mere mineral water may,

under certain conditions, assume the outward form of organic bodies—so this mineral substance, carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature; and if no such conception is at present held to be admissible, it is because long and varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If any one were to try to persuade you that an oyster shell (which is also chiefly composed of carbonate of lime) had crystallized out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that *Globigerina* is not the product of anything but vital activity.

Happily, however, better evidence in proof of the organic nature of the *Globigerinæ* than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the *Globigerinæ* of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of the seashore, over a large extent of that part of the earth's surface which is covered by the ocean.

The history of the discovery of these living *Globigerinæ,* and of the part which they play in rock building, is sin-

gular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very different and exceedingly practical interests. When men first took to the sea, they speedily learned to look out for shoals and rocks; and the more the burden of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding line; and, ultimately, marine surveying, which is the recording of the form of coasts and of the depth of the sea, as ascertained by the sounding-lead, upon charts.

At the same time, it became desirable to ascertain and to indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by "arming" the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieut. Brooke, of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up from any depth to which the lead descends. In 1853, Lieut. Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland and the

Azores, at a depth of more than 10,000 feet, or two miles, by the help of this sounding apparatus. The specimens were sent for examination to Ehrenberg of Berlin, and to Bailey of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms—the greater proportion of these being just like the *Globigerinæ* already known to occur in the chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieut. Brooke's method of sounding acquired a high commercial value, when the enterprise of laying down the telegraph cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly rope. The Admiralty consequently ordered Captain Dayman, an old friend and shipmate of mine, to ascertain the depth over the whole line of the cable, and to bring back specimens of the bottom. In former days, such a command as this might have sounded very much like one of the impossible things which the young Prince in the Fairy Tales is ordered to do before he can obtain the hand of the Princess. However, in the months of June and July, 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud

which he procured were sent to me to be examined and reported upon.*

The result of all these operations is, that we know the contours and the nature of the surface soil covered by the North Atlantic for a distance of 1,700 miles from east to west, as well as we know that of any part of the dry land. It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a wagon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And, except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie downhill for about 200 miles to the point at which the bottom is now covered by 1,700 fathoms of sea water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 feet; and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences, and gradually leads, for about 300 miles, to the Newfoundland shore.

* See Appendix to Captain Dayman's *Deep-sea Soundings in the North Atlantic Ocean between Ireland and Newfoundland, made in H.M.S "Cyclops."* Published by order of the Lords Commissioners of the Admiralty, 1858. They have since formed the subject of an elaborate Memoir by Messrs. Parker and Jones, published in the *Philosophical Transactions* for 1865.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a grayish white friable substance. You can write with this on a blackboard, if you are so inclined; and, to the eye, it is quite like very soft, grayish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable *Globigerinæ* embedded in a granular matrix. Thus this deep-sea mud is substantially chalk. I say substantially, because there are a good many minor differences; but, as these have no bearing on the question immediately before us—which is the nature of the *Globigerinæ* of the chalk—it is unnecessary to speak of them.

Globigerinæ of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the *Globigerina* shell, or rather skeleton, owes its existence—and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind—without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface, long filamentous processes, which serve for arms and legs. Yet this amorphous particle, devoid of everything which, in the higher animals, we call organs, is capable of feeding, growing, and multiplying; of separating from the

ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living *Globigerinæ* have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life; and it is not so absolutely impossible as it might at first sight appear to be, that the *Globigerinæ* of the Atlantic sea-bottom do not live and die where they are found.

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of *Globigerinæ,* with the granules which have been mentioned, and some few other calcareous shells; but a small percentage of the chalky mud—perhaps at most some five per cent of it—is of a different nature, and consists of shells and skeletons composed of silex, or pure flint. These silicious bodies belong partly to the lowly vegetable organisms which are called *Diatomaceæ,* and partly to the minute and extremely simple animals, termed *Radiolaria.* It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface—where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these silicious organisms, though they are not heavier than the lightest dust, must have fallen, in some cases, through fifteen thousand feet of water, before they reached their final restingplace on the ocean floor. And considering how large a surface these bodies expose in proportion to their

weight, it is probable that they occupy a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

But if the *Radiolaria* and *Diatoms* are thus rained upon the bottom of the sea, from the superficial layer of its waters in which they pass their lives, it is obviously possible that the *Globigerinæ* may be similarly derived; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea *Globigerinæ* are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating; and, as a matter of fact, they are not to be found along with the *Diatoms* and *Radiolaria* in the uppermost stratum of the open ocean. It has been observed again, that the abundance of *Globigerinæ*, in proportion to other organisms of like kind, increases with the depth of the sea; and that deep-water *Globigerinæ* are larger than those which live in shallower parts of the sea; and such facts negative the supposition that these organisms have been swept by currents from the shallows into the deeps of the Atlantic. It therefore seems to be hardly doubtful that these wonderful creatures live and die at the depths in which they are found.*

* During the cruise of H.M.S. *Bulldog*, commanded by Sir Leopold M'Clintock, in 1860, living star-fish were brought up, clinging to the lowest part of the sounding-line, from a depth of 1,260 fathoms, midway between Cape Farewell, in Greenland, and the Rockall banks. Dr. Wallich ascertained that the sea-bottom at this point consisted of the ordinary *Globigerina*

However, the important points for us are, that the living *Globigerinæ* are exclusively marine animals, the skeletons of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the *Globigerinæ* of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

In working over the soundings collected by Captain Dayman, I was surprised to find that many of what I have called the "granules" of that mud were not, as one might have been tempted to think at first, the mere powder and waste of *Globigerinæ*, but that they had a definite form and size. I termed these bodies *"coccoliths,"* and doubted their organic nature. Dr. Wallich verified my observation, and added the interesting discovery that, not unfrequently, bodies similar to these "coccoliths" were aggregated together into spheroids, which he termed *"coccospheres."* So far as we knew, these bodies, the nature of which is extremely puzzling and problematical, were peculiar to the Atlantic soundings. But, a few years ago, Mr. Sorby, in making a careful examination of the chalk by means of thin sections and otherwise, observed, as Ehrenberg had done before him, that much

ooze, and that the stomachs of the star-fishes were full of *Globigerinæ*. This discovery removes all objections to the existence of living *Globigerinæ* at great depths, which are based upon the supposed difficulty of maintaining animal life under such conditions; and it throws the burden of proof upon those who object to the supposition that the *Globigerinæ* live and die where they are found.

of its granular basis possesses a definite form. Comparing these formed particles with those in the Atlantic soundings, he found the two to be identical; and thus proved that the chalk, like the soundings, contains these mysterious coccoliths and coccospheres. Here was a further and most interesting confirmation, from internal evidence, of the essential identity of the chalk with modern deep-sea mud. *Globigerinæ,* coccoliths, and coccospheres are found as the chief constituents of both, and testify to the general similarity of the conditions under which both have been formed.*

The evidence furnished by the hewing, facing, and superposition of the stones of the Pyramids, that these structures were built by men, has no greater weight than the evidence that the chalk was built by *Globigerinæ;* and the belief that those ancient pyramid-builders were terrestrial and air-breathing creatures like ourselves, is not better based than the conviction that the chalk-makers lived in the sea. But as our belief in the building of the Pyramids by men is not only grounded on the internal evidence afforded by these structures, but gathers strength from multitudinous collateral proofs, and is clinched by the total absence of any reason for a contrary belief; so the evidence drawn from the *Globigerinæ* that the chalk is an ancient sea-bottom, is fortified by innumerable independent lines of evidence; and our belief in the truth

* I have recently traced out the development of the "coccoliths" from a diameter of $\frac{1}{7000}$th of an inch up to their largest size (which is about $\frac{1}{1600}$th), and no longer doubt that they are produced by independent organisms, which, like the *Globigerinæ,* live and die at the bottom of the sea.

of the conclusion to which all positive testimony tends, receives the like negative justification from the fact that no other hypothesis has a shadow of foundation.

It may be worth while briefly to consider a few of these collateral proofs that the chalk was deposited at the bottom of the sea. The great mass of the chalk is composed, as we have seen, of the skeletons of *Globigerinæ*, and other simple organisms, imbedded in granular matter. Here and there, however, this hardened mud of the ancient sea reveals the remains of higher animals which have lived and died, and left their hard parts in the mud, just as the oysters die and leave their shells behind them, in the mud of the present seas.

There are, at the present day, certain groups of animals which are never found in fresh waters, being unable to live anywhere but in the sea. Such are the corals; those coral-lines which are called *Polyzoa:* those creatures which fabricate the lamp-shells, and are called *Brachiopoda:* the pearly *Nautilus*, and all animals allied to it; and all the forms of seaurchins and star-fishes. Not only are all these creatures confined to salt water at the present day; but, so far as our records of the past go, the conditions of their existence have been the same: hence, their occurrence in any deposit is as strong evidence as can be obtained, that that deposit was formed in the sea. Now the remains of animals of all kinds which have been enumerated occur in the chalk, in greater or less abundance; while not one of those forms of shellfish which are characteristic of fresh water has yet been observed in it.

When we consider that the remains of more than three

thousand distinct species of aquatic animals have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water—the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land, at present occupied by the chalk, was once at the bottom of the sea, as we have for any matter of history whatever; while there is no justification for any other belief.

No less certain it is that the time during which the countries we now call southeast England, France, Germany, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration. We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me, that it must have taken some time for the skeletons of animalcules of a hundredth of an inch in diameter to heap up such a mass as that. I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shellfishes are commonly adherent; the long spines of some of the seaurchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as

much of the chalk as had then been deposited; and that each has been covered up by the layer of *Globigerina* mud, upon which the creatures imbedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

There is more curious evidence, again, that the process of covering up, or, in other words, the deposit of *Globigerina* skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose all its outward coverings and appendages by putrefaction; and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

Cases of this kind are admirably described by Sir Charles Lyell. He speaks of the frequency with which geologists find in the chalk a fossilized seaurchin, to which is attached the lower valve of a *Crania*. This is a kind of shellfish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

"The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white chalk at some distance. In this case, we see clearly that the seaurchin first lived from youth to age, then died and lost its spines, which were carried away. Then the young *Crania* adhered to the bared shell, grew and perished in its turn; after which, the upper valve was

separated from the lower, before the Echinus became enveloped in chalky mud." *

A specimen in the Museum of Practical Geology, in London, still further prolongs the period which must have elapsed between the death of the seaurchin and its burial by the *Globigerinæ*. For the outward face of the valve of a *Crania*, which is attached to a seaurchin *(Micraster)*, is itself overrun by an incrusting coralline, which spreads thence over more or less of the surface of the seaurchin. It follows that, after the upper valve of the *Crania* fell off, the surface of the attached valve must have remained exposed long enough to allow of the growth of the whole coralline, since corallines do not live embedded in mud.

The progress of knowledge may, one day, enable us to deduce from such facts as these the maximum rate at which the chalk can have accumulated, and thus to arrive at the minimum duration of the chalk period. Suppose that the valve of the *Crania* upon which a coralline has fixed itself in the way just described, is so attached to the seaurchin that no part of it is more than an inch above the face upon which the seaurchin rests. Then, as the coralline could not have fixed itself, if the *Crania* had been covered up with chalk mud, and could not have lived had itself been so covered, it follows that an inch of chalk mud could not have accumulated within the time between the death and decay of the soft parts of the seaurchin and the growth of the coralline to the full size which it has attained. If the decay of the soft parts of

* *Elements of Geology*, by Sir Charles Lyell, Bart., F.R.S., p. 23.

the seaurchin; the attachment, growth to maturity, and decay of the *Crania;* and the subsequent attachment and growth of the coralline, took a year (which is a low estimate enough), the accumulation of the inch of chalk must have taken more than a year: and the deposit of a thousand feet of chalk must, consequently, have taken more than twelve thousand years.

The foundation of all this calculation is, of course, a knowledge of the length of time the *Crania* and the coralline needed to attain their full size; and, on this head, precise knowledge is at present wanting. But there are circumstances which tend to show that nothing like an inch of chalk has accumulated during the life of a *Crania;* and, on any probable estimate of the length of that life, the chalk period must have had a much longer duration than that thus roughly assigned to it.

Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom; but it is no less certain that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began, or ended, its existence, is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made, in various parts of Western Europe, of flint implements, obviously worked into shape by human hands,

under circumstances which show conclusively that man is a very ancient denizen of these regions. It has been proved that the whole populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days different from what it is now—the river Somme, for instance, having cut its bed a hundred feet deeper between that time and this; and, it is probable, that the climate was more like that of Canada or Siberia than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne or of Amiens are to them, as they are to us, in point of antiquity. But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or bowlder clay, which, in comparison with the chalk, is but a very juvenile deposit. You need go no further than your own seaboard for evidence of this fact. At one of the most charming spots on the coast of Norfolk, Cromer, you will see the bowlder clay forming a vast mass, which lies upon the chalk, and must consequently have come into existence after it. Huge bowlders of chalk are, in fact, included

in the clay, and have evidently been brought to the position they now occupy by the same agency as that which has planted blocks of syenite from Norway side by side with them.

The chalk, then, is certainly older than the bowlder clay. If you ask how much, I will again take you no further than the same spot upon your own coasts for evidence. I have spoken of the bowlder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer, containing vegetable matter. But that layer tells a wonderful history. It is full of stumps of trees standing as they grew. Fir trees are there with their cones, and hazel bushes with their nuts; there stand the stools of oak and yew trees, beeches, and alders. Hence this stratum is appropriately called the "forest-bed."

It is obvious that the chalk must have been upheaved and converted into dry land, before the timber trees could grow upon it. As the boles of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed remained in the same condition for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn. When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these

great grinders crunch, in the dark woods of which the forest bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game the spoils of which have rejoiced your geologists. How long it remained in that condition cannot be said; but "the whirligig of time brought its revenges" in those days as in these. That dry land, with the bones and teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and bowlder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among the topmost twigs of the fir trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more, the wolf and the beaver replaced the reindeer and the elephant; and at length what we call the history of England dawned.

Thus you have, within the limits of your own county, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind. But we may go further and demonstrate, by evidence of the same authority as that which testifies to the existence of the father of men, that the chalk is vastly older than

Adam himself. The Book of Genesis informs us that Adam, immediately upon his creation, and before the appearance of Eve, was placed in the Garden of Eden. The problem of the geographical position of Eden has greatly vexed the spirits of the learned in such matters, but there is one point respecting which, so far as I know, no commentator has ever raised a doubt. This is, that of the four rivers which are said to run out of it, Euphrates and Hiddekel are identical with the rivers now known by the names of Euphrates and Tigris. But the whole country in which these mighty rivers take their origin, and through which they run, is composed of rocks which are either of the same age as the chalk, or of later date. So that the chalk must not only have been formed, but, after its formation, the time required for the deposit of these later rocks, and for their upheaval into dry land, must have elapsed, before the smallest brook which feeds the swift stream of "the great river, the river of Babylon," began to flow.

Thus, evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity, compels you to believe that the earth, from the time of the chalk to the present day, has been the theater of a series of changes as vast in their amount as they were slow in their progress. The area on which we stand has been first sea and then land, for at least four alternations; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch,"

not one of the present great physical features of the globe was in existence. Our great mountain ranges—Pyrenees, Alps, Himalayas, Andes—have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai and Ararat. All this is certain, because rocks of cretaceous, or still later, date have shared in the elevatory movements which gave rise to these mountain chains; and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though, in Norfolk, the forest-bed rests directly upon the chalk, yet it does so, not because the period at which the forest grew immediately followed that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred, before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But, great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants. All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those

which now live. Certainly not one of the higher animals was of the same species as any of those now in existence. The beasts of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely further back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia before it was colonized. We should see mammals, birds, reptiles, fishes, insects, snails, and the like, clearly recognizable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present, the population of the world has undergone slow and gradual, but incessant, changes. There has been no grand catastrophe—no destroyer has swept away the forms of life of one period, and replaced them by a totally new creation: but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led from one to the other by the most gradual progress, if we follow the course of Nature through the whole series of those relics of her operations which she has left behind. It is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms

of life. Thus the chalk contains remains of those strange flying and swimming reptiles, the pterodactyl, the ichthyosaurus, and the plesiosaurus, which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

But amongst these fading remainders of a previous state of things are some very modern forms of life, looking like Yankee peddlers among a tribe of Red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living shellfish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species, from those which existed at that remote epoch. The *Globigerina* of the present day, for example, is not different specifically from that of the chalk; and the same may be said of many other *Foraminifera.* I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity; but the only example which I can at present give confidently is the snake's-head lamp-shell *(Terebratulina caput serpentis),* which lives in our English seas and abounded (as *Terebratulina striata* of authors) in the chalk.

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shellfish. We Englishmen are proud to have an ancestor who was present at the Battle of Hastings. The ances-

tors of *Terebratulina caput serpentis* may have been present at a battle of *Ichthyosauria* in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. When all around has changed, this *Terebratulina* has peacefully propagated its species from generation to generation, and stands to this day as a living testimony to the continuity of the present with the past history of the globe.

Up to this moment I have stated, so far as I know, nothing but well-authenticated facts, and the immediate conclusions which they force upon the mind. But the mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation.

Taking the many changes of any given spot of the earth's surface, from sea to land and from land to sea, as an established fact, we cannot refrain from asking ourselves how these changes have occurred. And when we have explained them—as they must be explained—by the alternate slow movements of elevation and depression which have affected the crust of the earth, we go still further back, and ask, Why these movements?

I am not certain that any one can give you a satisfactory answer to that question. Assuredly I cannot. All that can be said for certain is, that such movements are part of the ordinary course of nature, inasmuch as they are going on at the present time. Direct proof may be given, that some parts of the land of the northern hemisphere are at this moment insensibly rising and others insensibly sinking; and there is indirect but perfectly satisfactory proof, that an enormous area now covered by

the Pacific has been deepened thousands of feet, since the present inhabitants of that sea came into existence. Thus there is not a shadow of a reason for believing that the physical changes of the globe, in past times, have been effected by other than natural causes. Is there any more reason for believing that the concomitant modifications in the forms of the living inhabitants of the globe have been brought about in other ways?

Before attempting to answer this question, let us try to form a distinct mental picture of what has happened in some special case. The crocodiles are animals which, as a group, have a very vast antiquity. They abounded ages before the chalk was deposited; they throng the rivers in warm climates, at the present day. There is a difference in the form of the joints of the backbone, and in some minor particulars, between the crocodiles of the present epoch and those which lived before the chalk; but, in the cretaceous epoch, as I have already mentioned, the crocodiles had assumed the modern type of structure. Notwithstanding this, the crocodiles of the chalk are not identically the same as those which lived in the times called "older tertiary," which succeeded the cretaceous epoch; and the crocodiles of the older tertiaries are not identical with those of the newer tertiaries, nor are these identical with existing forms. I leave open the question whether particular species may have lived on from epoch to epoch. But each epoch has had its peculiar crocodiles; though all, since the chalk, have belonged to the modern type, and differ simply in their proportions, and in such structural particulars as are discernible only to trained eyes.

How is the existence of this long succession of different species of crocodiles to be accounted for? Only two suppositions seem to be open to us. Either each species of crocodile has been specially created, or it has arisen out of some preëxisting form by the operation of natural causes.

Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense, in the simple words in which the writer of Genesis records the proceedings of the fifth and sixth days of the Creation.

On the other hand, I see no good reason for doubting the necessary alternative, that all these varied species have been evolved from preëxisting crocodilian forms, by the operation of causes as completely a part of the common order of nature as those which have effected the changes of the inorganic world. Few will venture to affirm that the reasoning which applies to crocodiles loses its force among other animals, or among plants. If one series of species has come into existence by the operation of natural causes, it seems folly to deny that all may have arisen in the same way.

A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this physical metamorphosis is no false image of what has

been the result of our subjecting it to a jet of fervent, though nowise brilliant, thought to-night. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting "without haste, but without rest" of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

V

FROM THE HUT TO THE PANTHEON

[This is the only article which Huxley ever wrote especially for an American periodical. It was published in the *Youth's Companion* in 1886; and it is included in this present volume by the kind permission of the owner of that weekly. Huxley seems to have overlooked it in the preparation of his "Collected Essays" in 1894; and apparently it has never been published in England.

Yet it is one of his most characteristic papers, displaying not only his mastery of exposition but also the wide range of his interest in the varied activities of mankind. It is an introduction to the study of the history of architecture, as enticing as the lectures on "A Lobster" and "On a Piece of Chalk," which were introductions respectively to Zoölogy and Geology. It is as conscientiously composed as were those earlier papers, the first of which antedated this by a quarter of a century. It is interesting to note how Huxley, although he was now writing for the eye of the reader rather than for the ear of the hearer, does not fail to bestow on this paper the same logical movement which seizes our attention in the two oral compositions.]

V

FROM THE HUT TO THE PANTHEON

[1887]

I

In one of the low-lying regions of the city of Rome, so low, in fact, that it is flooded whenever the Tiber rises a few feet above its ordinary level, there stands a huge cylindrical edifice which nearly fills up one side of an open paved space—the Piazza della Rotonda. The exterior of this great building looks worn and battered; and time, or the hand of the spoiler, or both together, have stripped off an outer casing and left bare the somewhat unsightly ends of the bricks which rise tier upon tier, and are here and there arranged in blind arches as if to give greater strength to the fabric.

Standing well back of the opposite side of the Piazza one can just see the top of a domed roof, most of which is hidden within the upper circle of the outer wall. But there is nothing to attract the eye except a stately columned portico; and even this is placed at a disadvantage, because the ground slopes downward to the great doors which are overshadowed by it.

This is the famous Pantheon. Notwithstanding the

ravages of "winter and foul weather," and the still worse mischief worked by foreign and native barbarians, especially the latter, it is the most perfect relic of imperial Rome in existence. Though the statues which once adorned it within and without have long since vanished; and though, centuries ago, the bronze panels and beams of the portico went into a papal melting-pot, to reappear, partly as cannon in the walls of the castle of St. Angelo, and partly as the columns of the hideous canopy over the shrine of St. Peter in the great church on the Vatican Hill; yet the substantial features of the building remain very much what they were, when, nineteen centuries ago, it rose under the eyes of Augustus. But the baths of Caracalla, the Coliseum, and the basilica of Constantine, which were built long afterwards, some of them centuries later than the Pantheon, are now nothing but mighty ruins.

It is fortunate that the heirloom which has thus been transmitted to modern Rome is one of the most valuable of all the possessions of the ancient city. The unattractive exterior disguises a perfect jewel of interior architecture; and when I was in Rome in the winter of 1884–85, I never passed through the Piazza della Rotonda without entering the venerable fane to renew my delight in it. There is but one adequate description of the general effect of the interior of the Pantheon that I know of:

"They went in, accordingly, and stood in the free space of that great circle, around which are ranged the arched recesses and stately altars, formerly dedicated to heathen gods, but Christianized through twelve centuries gone by. The world has nothing else like the Pantheon. . . .

"The rust and dinginess that have dimmed the precious marble on the walls; the pavement, with its great squares and rounds of porphyry and granite, cracked crosswise and in a hundred directions, showing how roughly the troublesome ages have trampled here; the gray dome above, with its opening to the sky, as if heaven were looking down into the interior of this place of worship, left unimpeded for prayers to ascend the more freely; all these things make an impression of solemnity which St. Peter's, itself, fails to produce."

I hope that the American youth whom I address do not fail to acquaint themselves with the works of the great writers of their own age and country—and, if so, they will know that I have borrowed from "The Marble Faun." Perhaps they are less familiar with the romance of "Monte Beni" than with the "House of Seven Gables," or "The Scarlet Letter"; and, to those who are unacquainted with Rome, it may well be that the Italian story is less attractive than the others. But to those who know that place of ruins and retrospections, there is something in the pure and sad sobriety of tone, the suggestive half-lights and mysterious shadows of Hawthorne's picture of the city which boasts itself eternal, which is wonderfully fascinating and true to nature.

I have omitted a paragraph about "dusty, artificial flowers, and all manner of trumpery gewgaws hanging at the saintly shrines," partly because it seems to jar a little, and partly because the evil is less rampant now than it was in Hawthorne's time. As the resting place of Victor Emanuel, the Pantheon is out of favor with the Papalini; and I think that, at present, it is the only Roman

church, with the exception of St. Paolo-fuori le Mura, the interior of which is not ruined by the bad taste of devout decorators.

The architect of the Pantheon must have been a master of his craft; and it is sad that his name and fame have long since vanished into oblivion. When M. Agrippa, the friend and minister of Augustus, at whose cost the edifice was built, gave him his commission, he seems to have resolved to construct something which should be eminently and characteristically Roman; perfectly simple, exquisitely beautiful, and yet of great majesty; withal so enduring that it should stand unscathed for two thousand years in the most storm-worn city of the world, while every monument of similar antiquity was brought low. And if the unknown architect did thus aspire to leave a witness of his unsurpassable skill for the admiration and the envy of future ages, he has undoubtedly succeeded.

The durability of the Pantheon speaks for itself: The late eminent French architect, Viollet-le-Duc, declares that, of all the great domes now in existence, that of the Pantheon alone remains without flaw. I have given better authority than my own for its beauty and its grandeur; but as to its simplicity and its eminently Roman character, I have somewhat to say.

Beauty, as a general rule, implies simplicity; I do not mean the simplicity of monotony, but the simplicity of unity. That which is highly and nobly beautiful always conveys an impression of balance, harmony, or rhythm; the parts, however various they may be, are related in a way which produces an intellectual satisfaction. Mind agi-

tates the mass of sensible impressions; the inner order shines through them and appeals to the reason.

For a long time, I was perplexed to know what it was about the proportions of the interior of the Pantheon which gave me such a different feeling from that made by any other domed space I had ever entered. But on studying an architectural section of the building, I believe I found the key to my problem, for its form results from the combination of two extremely simple geometrical figures, a sphere and a cylinder.

Take a sphere and a cylinder, the latter being of the same diameter as the sphere, and of the same height as its diameter. Then cut the sphere into two hemispheres and the cylinders into two cylinders of equal height—that is to say, of height equal to the radius of the sphere. Next stick one hemisphere by its flat side on to the flat top of one of the half cylinders; take a cast of the whole in papier-mâché, or some such material, and cut a circular hole in the summit of the hemisphere. The result will be a tolerably exact model of the interior of the Pantheon, which measures about 140 feet from the summit of the dome to the center of the circular floor, while this is about 140 feet in diameter. Nothing can be much simpler than such a combination of sphere and cylinder; and I conceive that this extreme simplicity lies at the foundation of the beauty of the result, while grandeur is conferred by the vast size of the whole. And both these æsthetic qualities are not a little heightened by the magical illumination yielded by the great, round, solitary toplight, in which the bright blue sky is framed like a heavenly window by day; while, by night, the "unhasting but

unresting" procession of the stars, from east to west, marks the ceaseless passage of all things from a past to a future eternity.

I have said that the Pantheon is an eminently and characteristically Roman work. In fact, the constructor of its vast, domed roof must have been familiar with the building of arches of great span; and the Romans are the only ancient people who have left evidence that they had attained to this great degree of architectural skill. The great hall of the temple of Karnak and the temple of Neptune at Paestum impress one as unsurpassable masterpieces in their several styles, but there is nothing to show that any Egyptian or Greek architect attempted the construction of a wide arch or a large dome.

Prof. G. Baldwin Brown, in his recently published interesting work, "From Schola to Cathedral," though he seems inclined to suspect that the Romans may have been the debtors of the Greeks, in arch-building as in so many other things, yet declares emphatically that "The first monumental dome, of which we have either remains or a clear record, is the cupola erected by the architect of Marcus Agrippa over the drum of the Pantheon, some time before the year 27 B. C."

In the article to which I referred above, Viollet-le-Duc has explained how the Roman architects, by the employment of an ingenious combination of concrete with brick, contrived to build their great arches and domes, with comparatively little outlay upon scaffolding, or, indeed, upon any work requiring skilled labor. The success of this method of construction must have depended largely

THE PANTHEON, ROME

upon the extraordinary strength of their concrete, owing to the use of puzzuolana in its preparation. This substance, however, is abundantly furnished by the volcanic districts of Italy; and it seems not improbable that the apparently sudden and unprecedented development of arched forms of building in old Rome may be connected with the discovery, by some adventurous builder, of the singular trustworthiness of Roman cement.

However this may be, there seems to be little doubt that all known domed and arched structures of any magnitude are traceable to Roman precedents.

II

There is another aspect under which the Pantheon may be regarded as an eminently characteristic product of old Italian life. Great and manifold as have been the differences of opinion as to the exact purpose for which the Pantheon was destined, it is now indubitable, firstly, that it was a sanctuary; and secondly, that, in the technical sense, it was not a temple. In order to have the technical status of a *templum* in old Rome, a building and the space in which it stood must be consecrated by those rites which the Augurs alone were competent to perform, and these required that the building should be rectangular. An edifice devoted to sacred purposes which was other than rectangular appears to have had, strictly speaking, no claim to the title of a templum, but was called a sacred *ædes* or *fanum*. Nevertheless, it would be a great mis-

take to suppose that less sanctity necessarily attached to an ædes than to a templum.

On the contrary, the oldest and most highly venerated of the Roman sanctuaries were ædes; and among them, the small, circular, dome-roofed building dedicated to Vesta, the foundations of which are yet traceable in the Forum at the foot of the Palatine Hill, held the highest place. This sanctuary contained no image of the goddess; but, day and night, her representative, the sacred fire, was kept burning upon the solitary altar by virgin priestesses, selected from the noblest patrician families, whose neglect of their duties or violation of their obligations was visited with the cruelest punishment.

The fire, which thus continually burned upon the hearth of Vesta, was venerated as the symbol and personification of the bonds which connected the members of every household with one another, and which united the households into their groups of higher order, the gens, the curia, the tribe, so as to bind the citizens of Rome into one organic whole. In all public supplications of the gods, the name Vesta came first, and with this recognized precedence and importance it seems, at first, singular that the sanctuary of such a high divinity should have taken the form of an insignificant ædes in the valley of the Forum; while, on the summit of the Capitoline Hill—the most conspicuous site in all Rome—splendid temples were erected to other gods and goddesses.

The explanation of this apparent anomaly is to be sought in the origin and nature of the worship of Vesta. Rome appears to have been founded by the union into a confederation of independent villages, settled upon the

Quirinal, Palatine, Capitoline, and perhaps others of the hills, which rise upon the left bank of the Tiber, and are, in fact, spurs of the eastern boundary wall of the deep valley which the Tiber has cut through this volcanic plateau of the Campagna.

The inhabitants of these villages lived in round huts, built of stakes, wattles, and thatch, with high pitched roofs, provided with a hole, at or near the top, to let out the smoke, the likenesses of which are preserved, not only in the very ancient urns of baked clay for holding the ashes of the dead, which are to be seen in the Museums of Rome, but in the huts of the shepherds of the Campagna at the present day. Each hut belonged to a family. It had a hearth on which the household fire had burned, generation after generation, before the images of the tutelary gods, representing the ancestors to whom the family traced its origin and on the continuance of whose protection the welfare of the family was believed to depend.

In all probability there was in each village a special hut, with its constant fire on the hearth, dedicated to the real or imaginary ancestors of all the families which composed it. And, when the various, previously independent villages confederated to form the community or city of Rome, they seem, in like manner, to have set apart a hut, built on the common ground between the hills, to serve as a meeting or market place, as the outward and visible sign of the new social bond.

This hut represented the homesteads of the city; its hearth and fire, all the hearths and fires; its goddess Vesta all the ties of citizenship conceived as religious obligations; while the Vestals were an undying family, actually,

and not merely metaphorically, representative of the life of the city from generation to generation.

It is a curious illustration of the tenacity with which the Roman adhered to ancient customs, that on the one day of the year on which the Vestal fire was permitted to go out, it was originally obliged to be relighted by the primitive method of rubbing one piece of wood against another. If conservatism held this length in so small a matter as lighting the fire, it is not wonderful that, however the growth of art and of wealth might affect the form and dimensions of other buildings, the ædes Vestæ underwent no essential alteration, in these respects, in the long duration of pagan Rome. Stone and bronze might be substituted for wattles and thatch as Ovid tells us they were:

> "Where now is bronze, a thatch of straw was seen,
> And a wall woven out of pliant wythes."

But, to the end, the sanctuary of Vesta retained the general form and dimensions of the hut in which it originated.

Architecturally speaking, however, the Pantheon is little more than an ædes Vestæ on a gigantic scale. Therefore, it is the old Italic hut magnified and transfigured, with the smoke-hole turned into a top-light. Or, to put the matter in another way, the round hut, the ædes Vestæ, and the Pantheon are so many stages in a process of architectural evolution which was effected between the first beginnings of Roman history and the Augustan age.

It would not be correct to say that the first term of this series—the round hut—is exclusively Roman or even Italic, for such huts were the ordinary dwelling places of Gauls and Teutons when the Romans first came in contact with them; and similar huts are built by savages in the most distant parts of the world at the present day.

But, in one sense, the Pantheon is really the flower of a thoroughly Italic seed, inasmuch as it can be proved that the practice of constructing habitations in the form of round huts was widely prevalent and of immeasurable antiquity in Italy. Throughout the peninsula, from the great "Padane Plain," traversed by the Po and its innumerable affluents as they wind their way to the Adriatic in the north, to Calabria in the south, abundant remains of the works of prehistoric men have been discovered by the zealous and able anthropologists of Italy. In that country, as elsewhere in Europe, the oldest gravels and cave deposits have yielded remains of human handiwork in the shape of chipped-stone implements of the most archaic type. Ground stone implements succeed these, and are followed, in deposits of a later epoch, by bronze-work, after which come the remains of the iron weapons and tools with which the ancient inhabitants of Italy were provided at the dawn of history.

The relative age of the stages of culture represented by the use of stone, bronze, and iron respectively is shown with remarkable clearness in various localities in Italy; though here, as in other cases, it is well to recollect that the use of the terms stone age, bronze age, and iron age is apt to mislead, unless one remembers that the several stages of this succession were by no means necessarily

contemporaneous in different localities. In places out of the reach of commercial or other external influences, the stone age might be fully represented, long after stone was superseded by bronze or iron elsewhere.

When I was in Torres Straits, in 1848, the people of some of the islands near the southeastern coast of New Guinea, far out of the way of the course of even Malay prahus, knew nothing about guns or gunpowder, and were still practically in the stone age, though they were greedy for iron. By this time, I dare say, they have passed not only into the iron but into the gunpowder, or perhaps I had better say dynamite age, and certainly without the intermediation of a bronze period.

Now it is a very interesting fact that, all over Italy, stone implements, without any trace of the use of bronze or iron, have been met with in certain circular patches of soil which first attracted attention by possessing a darker aspect than the adjacent ground. These patches are usually ten or twelve feet in diameter, and the dark soil which distinguishes them is found to be two or three feet deep. Its peculiar color arises from the intermixture of remains of animal and vegetable food materials, with charred wood and ashes, the relics of the fuel of the fire which once served to warm and cook the food of a prehistoric Italian. The bones of stags, oxen, sheep, goats, pigs, cats, and beavers (but neither of dogs, nor of horses) have been met with. Fragments of rude pottery, handmade, sundried, or imperfectly baked and unglazed, harmonize with the other indications of a low social state.

The Italian anthropologists term these curious patches of soil "fondi di campanne," or "hut-floors." And the justice of this determination of their nature has been borne out by the discovery, in some cases, of remains of the circle of stakes which supported the wall (probably wattled and plastered with clay) of the hut, which one must imagine to have had an opening on one side for entrance, and probably a hole at the top for the exit of smoke. In fact, these prehistoric huts, or wigwams, must have been essentially similar to those of the modern Italian shepherds.

A number of these hut-floors are frequently found close together and obviously mark the site of a prehistoric village. Sometimes the remains of several hearths, one above the other, indicate long occupation of the same spot. In some cases, a rude earthen receptacle containing the ashes of a man has been found interred beneath the hearth, showing that, like uncivilized modern people, the prehistoric Italian of the stone age buried the dead in his own house. In fact, this custom was continued down to the historic age in Italy.

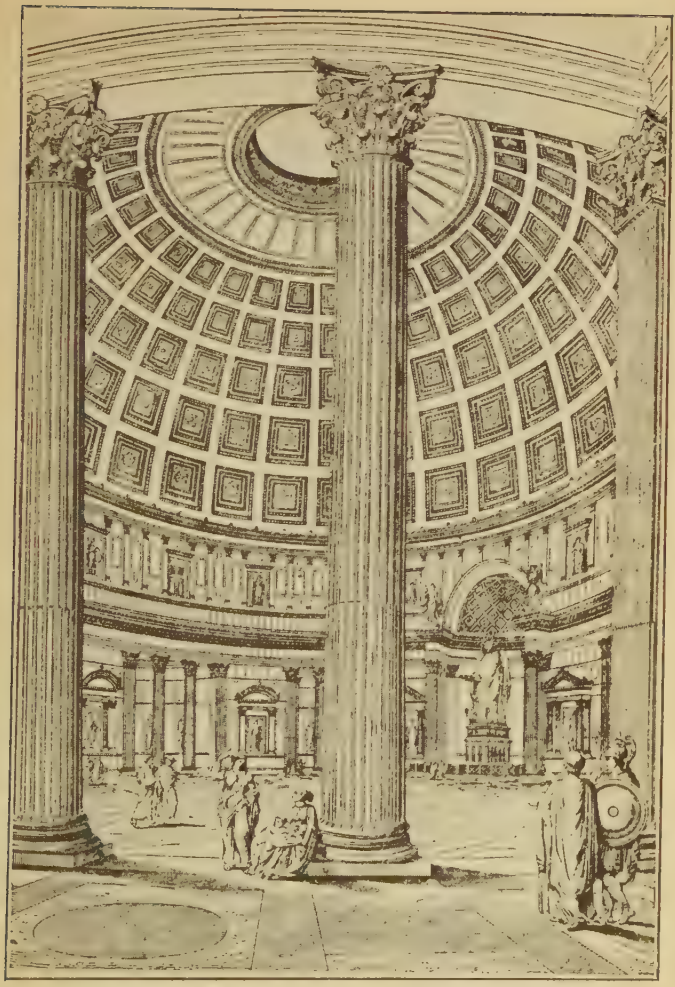
The grammarian, Servius, who wrote a commentary on the Æneid of Virgil and was deeply learned in Roman antiquities, affirms that in very ancient times, it was the custom to bury the dead in their houses, and he adds the very interesting remark that, in consequence of this, the household gods—the Lares and Penates—are worshipped in the houses. Hence the close association of the worship of the Manes, or deified ancestors, with the Lares and Penates, if, in fact, the latter were anything

but the Manes under another aspect—family ghosts told off to look after the household, as it were.

I have remarked above, that the evidence of the succession of bronze to stone, and of iron to bronze, is remarkably clear in some parts of Italy. In order to appreciate its cogency, we must leave the hut-floors and turn to the consideration of certain other very much more extensive areas of discolored soil which are known to the country people as "marniere" or "terremari." "Manure-earth" would probably be the most exact English equivalent for these terms, but, in anticipation of the exposition of their real nature, it will be more convenient to call these accumulations (which are in some respects analogous to the well-known "kitchen-middens" of Scandinavia, and elsewhere) "pile-middens."

Remains of nearly a hundred of these "pile-middens" have already been met with in different parts of the Padane plain, so that there can be no doubt that they must, formerly, have been very numerous. They are especially abundant in the neighborhood of Parma, Reggio, and Modena; and a good many occur in the space included between the Lago di Garda, on the north, and Mantua and Legnago, on the south.

A pile-midden is usually situated close to a stream (though well above its level); partly, no doubt, in order to secure a good supply of water to the people whose habitation it denotes. But, as Helbig has recently pointed out in his excellent work, "Die Italiker in der Po-Ebene," there was another reason for this vicinity to streams. In ancient times, the Padane plain, now so bare of trees, was covered by a dense forest of oaks,



THE PANTHEON (INTERIOR RESTORATION)

chestnuts, and elms; and the only openings and practicable roads lay in the course of the multitudinous rivers and rivulets which traverse it.

No doubt the first step of the people whose existence is made known to us by the pile-middens, was to take advantage of a natural clearing or to make an artificial one in these old Italian backwoods. They then laid out an oblong rectangular space, the area of which varies from three or four to twenty or more acres, the four sides of which appear to have been often, though not always, directed approximately toward the four points of the compass. They then dug out a deep ditch along these four sides and threw up the earth into an embankment four or five feet high, on the inner side of the ditch. In some cases, if not in all, the embankment was furnished with a firm foundation in the shape of a strong wooden framework, formed of planks joined at right angles to one another, and thus inclosing deep, box-like chambers. These were filled with earth and the earth was afterward heaped over the framework. Thus a fortified camp was formed, quite similar, in principle, to those with which the ancient Britons and the Romans have crowned many a hill in England. The eight or nine feet between the bottom of the ditch and the top of the embankment would confer no small advantage for defensive purposes, upon the dwellers within, even though they were not sheltered by the embankment but fought from the platform which we shall see rested on it.

Piles of wood, six to ten feet long, set from one to two or three feet apart, were driven perpendicularly into the

ground, throughout the inclosed space, until the tops of all the piles were on a level with the top of the embankment. A floor of wooden planking was then fixed to the tops of the piles and extended from the outermost row of these to the top of the embankment. Finally, the proper dwelling places, which appear to have been circular wattled huts, were built upon the firm floor thus laid. All the refuse from the huts dropped on to the ground beneath the platform and accumulated in a midden, until it gradually filled up the adjacent space.

One would think that, after a time, the people would have been forced to leave the unsavory residence and build another. But the attractions of home (sweet or otherwise) seem to have been strong for there is evidence in some cases that after they were crowded out by the ever-growing midden, another, and after this even yet another, set of new piles were driven in between and above the old ones, to form the foundation of a new village, the embankment being at the same time correspondingly elevated. It may be that, in some of these cases, the old village was destroyed by fires to which, whether they arose by accident or by the contrivance of enemies, such wooden constructions must have been very liable, in the hot dry summer of Italy.

It is the accumulation of refuse which gives its peculiar quality to the soil of the pile-middens and enables them to be recognized, even when all the woodwork has moldered away and the embankment has ceased to be distinguishable.

III

It will be readily understood that, in the course of the long years, perhaps centuries, during which the rubbish of the pile-middens accumulated, the pottery, implements, weapons, ornaments, and remains of food which dropped through by accident, as well as the refuse which was cast away by design, have been preserved, and thus furnish the means of forming a clear and comprehensive conception of the social condition of the people who dwelt in the huts above. But, before considering evidence of this kind, attention may be drawn to the obvious conclusion that the hewing, chipping, and transport of the immense quantities of wood employed in these constructions, no less than the digging out of the earth for the embankments, implies a great amount of systematic labor, and, consequently, a considerable population and a definite social organization among the people who built these pile dwellings. We should thus expect them to have reached a higher stage of civilization than the hut-floor people already mentioned. And this expectation is fully justified by the evidence of the remains already referred to.

The pottery is better made, though not yet glazed, and many of the vessels are provided with a peculiar and characteristic form of handle, which has been termed "ansate." The handle is, in fact, perforated in the middle, and its upper margin has a deep excavation. No doubt the forefinger was placed in the hole and the thumb in the excavation, and thus the handle was firmly grasped.

Iron is usually absent; bronze is abundant and is extensively used in the fabrication of axes and spearheads; while stone, though still employed for some kinds of implements and for arrowheads, retires into the background. The bronze is cast and not hammered, and the presence of molds shows that the people did their casting for themselves. But the rough bronze could have reached them only by way of commerce, neither copper nor tin being attainable in the Padane plain; and the existence of commerce is also proved by the occasional, though rare, occurrence of amber beads, the material of which probably came from the shores of the Baltic.

Though the predominance of bronze and the absence of iron characterize the pile-middens, in general, there are some in which iron makes its appearance, while there are others in which even bronze is rare or absent. However, speaking broadly, the pile-middens belong to the bronze age.

That the pile-midden people practiced agriculture on a large scale is rendered certain by the presence of abundant remains of wheat, beans, and vines. Moreover, as domesticated animals, they had oxen, sheep, goats, pigs, horses, and dogs. Stags, the roe-deer, the boars, which roamed in the Padane forests, furnished them with game; and some remains of bears indicate that they occasionally attacked more dangerous quarry. But, curiously enough, there are neither fishbones nor fishhooks; though the Po and its affluents abound in fish.

It is plain, then, that the people who have left their mark in the pile-middens had reached a grade of civilization which is by no means contemptible. Indeed, to all

appearance, it is quite as high as that attained by the Gauls and Germans, when they first appear in history; and it probably differed little from that of the Italic people in general not very long before the foundation of Rome. And that these people were more modern than the hut-builders of the stone age is rendered certain by the fact that hut-floors of that age have been found beneath the pile-middens; that is to say, the pile-driving people had built on the site of a deserted or destroyed, round-hut village of the stone age.

There is something so peculiar about the fashion of building piles, that the temptation to believe that all the people who adopted it were of one race is undoubtedly very strong. But there are sundry well-known facts which dictate great caution in adopting any such conclusion. Nobody has suggested, or is likely to suggest, that the pile-dwelling builders of Europe were either Malays or Papuans; yet at the present day, both Malays and Papuans build pile-dwellings of the same essential character, sometimes in the water and sometimes on dry land. Moreover the Malays and Papuans are as distinct from one another as any two races of mankind can be, in fact, as different as both are from Europeans; so that, if they were to become extinct, and no trace were left of them but their dwellings, the traveler from the Malay peninsula to the coasts of New Guinea and its adjacent islets, who should suppose that all the pile-dwellings he met with were fabricated by one and the same people, would fall into a prodigious error. Moreover there are Papuan people who build beehive-shaped, thatched huts; and, therefore, stand in the same architectural relation to

the other Papuans as the hut-floor people of Italy to the pile-driving people.

Hence, the facts adduced are wholly insufficient to justify any decided conclusion as to either the similarity or dissimilarity of the people to whom the grades of social organization indicated by the hut-floors on the one hand, and the pile-dwellings on the other, belong. They may be merely groups of one race, of which the later has reached a higher grade, by means of commerce and other external influences; or the later may be immigrants, of different blood from the primitive Italic stock, who brought a more advanced civilization with them.

However this may be, there is no reason to suppose that the round huts were at any time completely superseded (except in particular localities) by the pile-dwellings. No doubt they continued to exist contemporaneously with the pile-dwellings, in most parts of Italy; and, after the pile-dwellings ceased to be in fashion, the round huts again became practically universal. And it can be proved that the people who built them shared in the general progress of civilization, and passed through the bronze to the iron stage, until this primitive form of shelter obtained a permanent representative in the ædes Vestæ.

It has already been stated that the pile-middens are to be met with in the Padane plain as far north as the Lago di Garda. But, in the lake itself, there are constructions of the same essential character, in so far as they consist of wooden piles supporting a platform, on which huts are erected, over the water. That is to say, the piles are not driven into the dry land but into the bottom of a shallow part of the lake; whereby the latter plays the

part of a moat, and the ditch and the parapet become superfluous.

The aquatic pile-dwellings, found in this and other Italian lakes, again, are altogether similar to the constructions which of late years have attracted so much attention in Switzerland, and are known as "lake-dwellings." Traces of them have been discovered in many other parts of Europe and Sig. Pigorini has met with them as far east as the lower course of the Danube. As in Italy, the majority of these constructions belong to the bronze age; but, as in Italy, some are older and some are younger.

As the prehistoric round hut is the earliest stage of a developmental series which has culminated in the Pantheon, is there no corresponding process of evolution traceable in the pile-dwellings? In the Pandane plain itself, their chances of development appear to have been cut short by the Etruscans, a race of rude and superstitious warriors, who came over the Apennines, and whose chief significance seems to lie in the fact that they were the intermediaries by whom more or less of the culture of the Phœnician, and afterwards of the Greek, traders who reached their coast was transmitted to the old Italians.

At a later period, the Etruscan domination was swept away by the Gauls, whose big-boned skeletons, with their long iron swords by their sides, tell of the foundation of Bononia, the ancestress of modern Bologna, on the ruins of the Etruscan Felsina, which again was founded on the site of a nameless pile-dwelling town.

But the eastern fringe of the Pandane plain presents a conformation admirably adapted for the building of

aquatic pile-houses. The plain is, in fact, nothing but the flat, almost horizontal surface of the mud, sand, and gravel which, for thousands upon thousands of years, have been made out of fragments of the rocks of the Alps and the Apennines, split off by frost, washed away by rains, and ground down by glaciers, to be finally rounded and pulverized in mountain torrents and swept away to the lowest point attainable.

After filling up the vast valley between the two great mountain ranges of the Alps on the north, and the Apennines on the west and south, these deposits have gradually thrust themselves forward into the waters of the Adriatic, and have given rise to a great wilderness of swamps, islands, shoals, and lagoons, bounded on the sea-face by the long sand-bar of which the Venetian Lido forms a part.

No place of refuge could be better adapted for people who had learned how to make themselves at home in pile-dwellings; and, although I cannot say that there is any evidence which directly proves that the prehistoric pile-dwelling builders availed themselves of the advantages offered, yet it is quite certain that, in very ancient times, settlements of houses built on piles existed in the region in question. The old cities of Altinum and Atria were thus constructed, as was also Ravenna, the last refuge of the emperors of Rome. In later times, Grado, Torcella, and finally Venice, were built in the same fashion.

Thus, as the Pantheon lay potentially in the round hut of the stone age, so it seems more than probable that the germ of the Piazza of St. Mark, with its glorious Duomo, was contained in the prehistoric pile-dwellings of Italy.

VI

ON THE ADVISABLENESS OF IMPROVING NATURAL KNOWLEDGE

[This address was delivered in London at St. Martin's Hall, on the evening of the first Sunday of 1866; and Huxley chose this day of the week because he proposed to preach a Lay Sermon, that is, a reverent discourse by a layman on a lofty theme of large importance. In so doing, Huxley held himself to be truly a preacher of sound doctrine, expounding the truth that the improvement of the knowledge of the processes of nature is necessary for the salvation of the lives of men. He took occasion also to deny the erroneous opinion that this improvement resulted only in material benefit; and he had little difficulty in showing that it resulted also in spiritual benefit.

Layman as he was, Huxley was all his life a preacher. In his autobiography he records as a memory of his boyhood that one Sunday morning when the rest of the family were at church, he turned his pinafore wrong side forwards in order to represent a surplice and preached a sermon to his mother's maids in imitation of the vicar of the parish. Forty years later when he stood up on Sunday evening to utter this lay sermon he had no need to don ecclesiastical attire; but few of those who have worn it have ever equaled Huxley's sincerity, his earnestness, and his logic in setting forth the faith that was in him.]

VI

ON THE ADVISABLENESS OF IMPROVING NATURAL KNOWLEDGE

[1866]

This time two hundred years ago—in the beginning of January, 1666—those of our forefathers who inhabited this great and ancient city, took breath between the shocks of two fearful calamities: one not quite past, although its fury had abated; the other to come.

Within a few yards of the very spot on which we are assembled, so the tradition runs, that painful and deadly malady, the plague, appeared in the latter months of 1664; and, though no new visitor, smote the people of England, and especially of her capital, with a violence unknown before, in the course of the following year. The hand of a master has pictured what happened in those dismal months; and in that truest of fictions, "The History of the Plague Year," Defoe shows death, with every accompaniment of pain and terror, stalking through the narrow streets of old London, and changing their busy hum into a silence broken only by the wailing of the mourners of fifty thousand dead; by the woeful denun-

ciations and mad prayers of fanatics; and by the madder yells of despairing profligates.

But, about this time in 1666, the death rate had sunk to nearly its ordinary amount; a case of plague occurred only here and there, and the richer citizens who had flown from the pest had returned to their dwellings. The remnant of the people began to toil at the accustomed round of duty, or of pleasure; and the stream of city life bid fair to flow back along its old bed, with renewed and uninterrupted vigor.

The newly-kindled hope was deceitful. The great plague, indeed, returned no more; but what it had done for the Londoners, the great fire, which broke out in the autumn of 1666, did for London; and, in September of that year, a heap of ashes and the indestructible energy of the people were all that remained of the glory of five-sixths of the city within the walls.

Our forefathers had their own ways of accounting for each of these calamities. They submitted to the plague in humility and in penitence, for they believed it to be the judgment of God. But towards the fire they were furiously indignant, interpreting it as the effect of the malice of man—as the work of the Republicans, or of the Papists, according as their prepossessions ran in favor of loyalty or of Puritanism.

It would, I fancy, have fared but ill with one who, standing where I now stand, in what was then a thickly-peopled and fashionable part of London, should have broached to our ancestors the doctrine which I now propound to you—that all their hypotheses were alike wrong;

that the plague was no more, in their sense, Divine judgment, than the fire was the work of any political or of any religious sect; but that they were themselves the authors of both plague and fire, and that they must look to themselves to prevent the recurrence of calamities, to all appearance so peculiarly beyond the reach of human control—so evidently the result of the wrath of God, or of the craft and subtlety of an enemy.

And one may picture to one's self how harmoniously the holy cursing of the Puritan of that day would have chimed in with the unholy cursing and the crackling wit of the Rochesters and Sedleys, and with the revilings of the political fanatics, if my imaginary plain dealer had gone on to say that, if the return of such misfortunes were ever rendered impossible, it would not be in virtue of the victory of the faith of Laud, or of that of Milton; and, as little, by the triumph of republicanism, as by that of monarchy. But that the one thing needful for compassing this end was, that the people of England should second the efforts of an insignificant corporation, the establishment of which, a few years before the epoch of the great plague and the great fire, had been as little noticed as they were conspicuous.

Some twenty years before the outbreak of the plague a few calm and thoughtful students banded themselves together for the purpose, as they phrased it, of "improving natural knowledge." The ends they proposed to attain cannot be stated more clearly than in the words of one of the founders of the organization:

"Our business was (precluding matters of theology and

state affairs) to discourse and consider of philosophical enquiries, and such as related thereunto—as Physics, Anatomy, Geometry, Astronomy, Navigation, Statics, Magnetics, Chymics, Mechanics, and Natural Experiments; with the state of these studies and their cultivation at home and abroad. We then discoursed of the circulation of the blood, the valves in the veins, the venæ lacteæ, the lymphatic vessels, the Copernican hypothesis, the nature of comets and new stars, the satellites of Jupiter, the oval shape (as it then appeared) of Saturn, the spots on the sun and its turning on its own axis, the inequalities and selenography of the moon, the several phases of Venus and Mercury, the improvement of telescopes and grinding of glasses for that purpose, the weight of air, the possibility or impossibility of vacuities and nature's abhorrence thereof, the Torricellian experiment in quicksilver, the descent of heavy bodies and the degree of acceleration therein, with divers other things of like nature, some of which were then but new discoveries, and others not so generally known and embraced as now they are; with other things appertaining to what has been called the New Philosophy, which from the times of Galileo at Florence, and Sir Francis Bacon (Lord Verulam) in England, has been much cultivated in Italy, France, Germany, and other parts abroad, as well as with us in England."

The learned Dr. Wallis, writing in 1696, narrates in these words what happened half a century before, or about 1645. The associates met at Oxford, in the rooms of Dr. Wilkins, who was destined to become a bishop; and subsequently coming together in London, they at-

tracted the notice of the king. And it is a strange evidence of the taste for knowledge which the most obviously worthless of the Stuarts shared with his father and grandfather, that Charles the Second was not content with saying witty things about his philosophers, but did wise things with regard to them. For he not only bestowed upon them such attention as he could spare from his poodles and his mistresses, but, being in his usual state of impecuniosity, begged for them of the Duke of Ormond; and, that step being without effect, gave them Chelsea College, a charter, and a mace; crowning his favors in the best way they could be crowned, by burdening them no further with royal patronage or state interference.

Thus it was that the half-dozen young men, studious of the "New Philosophy," who met in one another's lodgings in Oxford or in London, in the middle of the seventeenth century, grew in numerical and in real strength, until, in its latter part, the "Royal Society for the Improvement of Natural Knowledge" had already become famous, and had acquired a claim upon the veneration of Englishmen, which it has ever since retained, as the principal focus of scientific activity in our islands, and the chief champion of the cause it was formed to support.

It was by the aid of the Royal Society that Newton published his "Principia." If all the books in the world, except the "Philosophical Transactions," were destroyed, it is safe to say that the foundations of physical science would remain unshaken, and that the vast intellectual progress of the last two centuries would be largely, though incompletely, recorded. Nor have any signs of halting or of decrepitude manifested themselves in our own times.

As in Dr. Wallis's days, so in these, "our business is, precluding theology and state affairs, to discourse and to consider philosophical enquiries." But our "Mathematick" is one which Newton would have to go to school to learn; our "Staticks, Mechanicks, Magneticks, Chymicks, and Natural Experiments" constitute a mass of physical and chemical knowledge, a glimpse at which would compensate Galileo for the doings of a score of inquisitorial cardinals; our "Physick" and "Anatomy" have embraced such infinite varieties of being, have laid open such new worlds in time and space, have grappled, not unsuccessfully, with such complex problems, that the eyes of Vesalius and of Harvey might be dazzled by the sight of the tree that has grown out of their grain of mustard seed.

The fact is perhaps rather too much, than too little, forced upon one's notice, nowadays, that all this marvelous intellectual growth has a no less wonderful expression in practical life; and that in this respect, if in no other, the movement symbolized by the progress of the Royal Society stands without a parallel in the history of mankind.

A series of volumes as bulky as the "Transactions of the Royal Society" might possibly be filled with the subtle speculations of the Schoolmen; not improbably, the obtaining a mastery over the products of medieval thought might necessitate an even greater expenditure of time and of energy than the acquirement of the "New Philosophy"; but though such work engrossed the best intel-

lects of Europe for a longer time than has elapsed since the great fire, its effects were "writ in water," so far as our social state is concerned.

On the other hand, if the noble first President of the Royal Society could revisit the upper air and once more gladden his eyes with a sight of the familiar mace, he would find himself in the midst of a material civilization more different from that of his day than that of the seventeenth was from that of the first century. And if Lord Brouncker's native sagacity had not deserted his ghost, he would need no long reflection to discover that all these great ships, these railways, these telegraphs, these factories, these printing presses, without which the whole fabric of modern English society would collapse into a mass of stagnant and starving pauperism—that all these pillars of our State are but the ripples and the bubbles upon the surface of that great spiritual stream, the springs of which only he and his fellows were privileged to see; and seeing, to recognize as that which it behooved them above all things to keep pure and undefiled.

It may not be too great a flight of imagination to conceive our noble *revenant* not forgetful of the great troubles of his own day, and anxious to know how often London had been burned down since his time, and how often the plague had carried off its thousands. He would have to learn that, although London contains tenfold the inflammable matter that it did in 1666; though, not content with filling our rooms with woodwork and light draperies, we must needs lead inflammable and explosive gases into every corner of our streets and houses, we never allow even a street to burn down. And if he

asked how this had come about, we should have to explain that the improvement of natural knowledge has furnished us with dozens of machines for throwing water upon fires, any one of which would have furnished the ingenious Mr. Hooke, the first "curator and experimenter" of the Royal Society, with ample materials for discourse before half a dozen meetings of that body; and that, to say truth, except for the progress of natural knowledge, we should not have been able to make even the tools by which these machines are constructed. And further, it would be necessary to add that although severe fires sometimes occur and inflict great damage, the loss is very generally compensated by societies, the operations of which have been rendered possible only by the progress of natural knowledge in the direction of mathematics, and the accumulation of wealth in virtue of other natural knowledge.

But the plague? My Lord Brouncker's observation would not, I fear, lead him to think that Englishmen of the nineteenth century are purer in life, or more fervent in religious faith, than the generation which could produce a Boyle, an Evelyn, and a Milton. He might find the mud of society at the bottom, instead of at the top, but I fear that the sum total would be as deserving of swift judgment as at the time of the Restoration. And it would be our duty to explain once more, and this time not without shame, that we have no reason to believe that it is the improvement of our faith, nor that of our morals, which keeps the plague from our city; but again, that it is the improvement of our natural knowledge.

We have learned that pestilences will only take up their

abode among those who have prepared unswept and ungarnished residences for them. Their cities must have narrow, unwatered streets, foul with accumulated garbage. Their houses must be ill-drained, ill-lighted, ill-ventilated. Their subjects must be ill-washed, ill-fed, ill-clothed. The London of 1665 was such a city. The cities of the East, where plague has an enduring dwelling, are such cities. We, in later times, have learned somewhat of Nature, and partly obey her. Because of this partial improvement of our natural knowledge and of that fractional obedience, we have no plague; because that knowledge is still very imperfect and that obedience yet incomplete, typhoid is our companion and cholera our visitor. But it is not presumptuous to express the belief that, when our knowledge is more complete and our obedience the expression of our knowledge, London will count her centuries of freedom from typhoid and cholera, as she now gratefully reckons her two hundred years of ignorance of that plague which swooped upon her thrice in the first half of the seventeenth century.

Surely, there is nothing in these explanations which is not fully borne out by the facts? Surely, the principles involved in them are now admitted among the fixed beliefs of all thinking men? Surely, it is true that our countrymen are less subject to fire, famine, pestilence, and all the evils which result from a want of command over and due anticipation of the course of Nature, than were the countrymen of Milton; and health, wealth, and well-being are more abundant with us than with them? But no less certainly is the difference due to the improvement of our knowledge of Nature, and the extent to

which that improved knowledge has been incorporated with the household words of men, and has supplied the springs of their daily actions.

Granting for a moment, then, the truth of that which the depreciators of natural knowledge are so fond of urging, that its improvement can only add to the resources of our material civilization; admitting it to be possible that the founders of the Royal Society themselves looked for no other reward than this, I cannot confess that I was guilty of exaggeration when I hinted, that to him who had the gift of distinguishing between prominent events and important events, the origin of a combined effort on the part of mankind to improve natural knowledge might have loomed larger than the Plague and have outshone the glare of the Fire; as a something fraught with a wealth of beneficence to mankind, in comparison with which the damage done by those ghastly evils would shrink into insignificance.

It is very certain that for every victim slain by the plague, hundreds of mankind exist and find a fair share of happiness in the world by the aid of the spinning jenny. And the great fire, at its worst, could not have burned the supply of coal, the daily working of which, in the bowels of the earth, made possible by the steam pump, gives rise to an amount of wealth to which the millions lost in old London are but as an old song.

But spinning jenny and steam pump are, after all, but toys possessing an accidental value; and natural knowledge creates multitudes of more subtle contrivances, the praises of which do not happen to be sung because they

are not directly convertible into instruments for creating wealth. When I contemplate natural knowledge squandering such gifts among men, the only appropriate comparison I can find for her is, to liken her to such a peasant woman as one sees in the Alps, striding ever upward, heavily burdened, and with mind bent only on her home; but yet without effort and without thought, knitting for her children. Now stockings are good and comfortable things, and the children will undoubtedly be much the better for them; but surely it would be short-sighted, to say the least of it, to depreciate this toiling mother as a mere stocking-machine—a mere provider of physical comforts?

However, there are blind leaders of the blind, and not a few of them, who take this view of natural knowledge, and can see nothing in the bountiful mother of humanity but a sort of comfort-grinding machine. According to them, the improvement of natural knowledge always has been, and always must be, synonymous with no more than the improvement of the material resources and the increase of the gratifications of men.

Natural knowledge is, in their eyes, no real mother of mankind, bringing them up with kindness, and, if need be, with sternness, in the way they should go, and instructing them in all things needful for their welfare; but a sort of fairy godmother, ready to furnish her pets with shoes of swiftness, swords of sharpness, and omnipotent Aladdin's lamps, so that they may have telegraphs to Saturn, and see the other side of the moon, and thank God they are better than their benighted ancestors

If this talk were true, I, for one, should not greatly

care to toil in the service of natural knowledge. I think I would just as soon be quietly chipping my own flint axe, after the manner of my forefathers, a few thousand years back, as be troubled with the endless malady of thought which now infests us all, for such reward. But I venture to say that such views are contrary alike to reason and to fact. Those who discourse in such fashion seem to me to be so intent upon trying to see what is above Nature, or what is behind her, that they are blind to what stares them in the face in her.

I should not venture to speak thus strongly if my justification were not to be found in the simplest and most obvious facts—if it needed more than an appeal to the most notorious truths to justify my assertion that the improvement of natural knowledge, whatever direction it has taken, and however low the aims of those who may have commenced it—has not only conferred practical benefits of men, but in so doing, has effected a revolution in their conceptions of the universe and of themselves, and has profoundly altered their modes of thinking and their views of right and wrong. I say that natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings. I say that natural knowledge, in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundations of a new morality.

Let us take these points separately; and first, what great ideas has natural knowledge introduced into men's minds?

I cannot but think that the foundations of all natural

knowledge were laid when the reason of man first came face to face with the facts of Nature; when the savage first learned that the fingers of one hand are fewer than those of both; that it is shorter to cross a stream than to head it; that a stone stops where it is unless it be moved, and that it drops from the hand which lets it go; that light and heat come and go with the sun; that sticks burn away in a fire; that plants and animals grow and die; that if he struck his fellow savage a blow he would make him angry, and perhaps get a blow in return, while if he offered him a fruit he would please him, and perhaps receive a fish in exchange. When men had acquired this much knowledge, the outlines, rude though they were, of mathematics, of physics, of chemistry, of biology, of moral, economical, and political science, were sketched. Nor did the germ of religion fail when science began to bud. Listen to words which, though new, are yet three thousand years old:

> ". . . When in heaven the stars about the moon
> Look beautiful, when all the winds are laid,
> And every height comes out, and jutting peak
> And valley, and the immeasurable heavens
> Break open to their highest, and all the stars
> Shine, and the shepherd gladdens in his heart." *

If the half savage Greek could share our feelings thus far, it is irrational to doubt that he went further, to find as we do, that upon that brief gladness there follows a certain sorrow—the little light of awakened human in-

* Need it be said that this is Tennyson's English for Homer's Greek?

telligence shines so mere a spark amidst the abyss of the unknown and unknowable; seems so insufficient to do more than illuminate the imperfections that cannot be remedied, the aspirations that cannot be realized, of man's own nature. But in this sadness, this consciousness of the limitation of man, this sense of an open secret which he cannot penetrate, lies the essence of all religion; and the attempt to embody it in the forms furnished by the intellect is the origin of the higher theologies.

Thus it seems impossible to imagine but that the foundations of all knowledge—secular or sacred—were laid when intelligence dawned, though the superstructure remained for long ages so slight and feeble as to be compatible with the existence of almost any general view respecting the mode of governance of the universe. No doubt from the first, there were certain phenomena which, to the rudest mind, presented a constancy of occurrence, and suggested that a fixed order ruled, at any rate, among them. I doubt if the grossest of Fetish worshipers ever imagined that a stone must have a god within it to make it fall, or that a fruit had a god within it to make it taste sweet. With regard to such matters as these, it is hardly questionable that mankind from the first took strictly positive and scientific views.

But, with respect to all the less familiar occurrences which present themselves, uncultured man, no doubt, has always taken himself as the standard of comparison, as the center and measure of the world; nor could he well avoid doing so. And finding that his apparently uncaused will has a powerful effect in giving rise to

many occurrences, he naturally enough ascribed other and greater events to other and greater volitions, and came to look upon the world and all that therein is, as the product of the volitions of persons like himself, but stronger, and capable of being appeased or angered, as he himself might be soothed or irritated. Through such conceptions of the plan and working of the universe all mankind have passed, or are passing. And we may now consider what has been the effect of the improvement of natural knowledge on the views of men who have reached this stage, and who have begun to cultivate natural knowledge with no desire but that of "increasing God's honor and bettering man's estate."

For example, what could seem wiser, from a mere material point of view, more innocent, from a theological one, to an ancient people, than that they should learn the exact succession of the seasons, as warnings for their husbandmen; or the position of the stars, as guides to their rude navigators? But what has grown out of this search for natural knowledge of so merely useful a character? You all know the reply. Astronomy—which of all sciences has filled men's minds with general ideas of a character most foreign to their daily experience, and has, more than any other, rendered it impossible for them to accept the beliefs of their fathers. Astronomy—which tells them that this so vast and seemingly solid earth is but an atom among atoms, whirling, no man knows whither, through illimitable space; which demonstrates that what we call the peaceful heaven above us, is but that space, filled by an infinitely subtle matter whose particles are seething and surging, like the waves of an

angry sea; which opens up to us infinite regions where nothing is known, or ever seems to have been known, but matter and force, operating according to rigid rules; which leads us to contemplate phenomena the very nature of which demonstrates that they must have had a beginning, and that they must have an end, but the very nature of which also proves that the beginning was, to our conceptions of time, infinitely remote, and that the end is as immeasurably distant.

But it is not alone those who pursue astronomy who ask for bread and receive ideas. What more harmless than the attempt to lift and distribute water by pumping it; what more absolutely and grossly utilitarian? Yet out of pumps grew the discussions about Nature's abhorrence of a vacuum; and then it was discovered that Nature does not abhor a vacuum, but that air has weight; and that notion paved the way for the doctrine that all matter has weight, and that the force which produces weight is co-extensive with the universe—in short, to the theory of universal gravitation and endless force. While learning how to handle gases led to the discovery of oxygen, and to modern chemistry, and to the notion of the indestructibility of matter.

Again, what simpler, or more absolutely practical, than the attempt to keep the axle of a wheel from heating when the wheel turns round very fast? How useful for carters and gig drivers to know something about this; and how good were it, if any ingenious person would find out the cause of such phenomena, and thence educe a general remedy for them. Such an ingenious person was Count Rumford; and he and his successors have landed

us in the theory of the persistence, or indestructibility, of force. And in the infinitely minute, as in the infinitely great, the seekers after natural knowledge of the kinds called physical and chemical, have everywhere found a definite order and succession of events which seem never to be infringed.

And how has it fared with "Physics" and Anatomy? Have the anatomist, the physiologist, or the physician, whose business it has been to devote themselves assiduously to that eminently practical and direct end, the alleviation of the sufferings of mankind—have they been able to confine their vision more absolutely to the strictly useful? I fear they are the worst offenders of all. For if the astronomer has set before us the infinite magnitude of space, and the practical eternity of the duration of the universe; if the physical and chemical philosophers have demonstrated the infinite minuteness of its constituent parts, and the practical eternity of matter and of force; and if both have alike proclaimed the universality of a definite and predicable order and succession of events, the workers in biology have not only accepted all these, but have added more startling theses of their own. For, as the astronomers discover in the earth no center of the universe, but an eccentric speck, so the naturalists find man to be no center of the living world, but one amidst endless modifications of life; and as the astronomer observes the mark of practically endless time set upon the arrangements of the solar system so the student of life finds the records of ancient forms of existence peopling the world for ages, which, in relation to human experience, are infinite.

Furthermore, the physiologist finds life to be as dependent for its manifestation on particular molecular arrangements as any physical or chemical phenomenon; and wherever he extends his researches, fixed order and unchanging causation reveal themselves, as plainly as in the rest of Nature.

Nor can I find that any other fate has awaited the germ of Religion. Arising, like all other kinds of knowledge, out of the action and interaction of man's mind, with that which is not man's mind, it has taken the intellectual coverings of Fetishism or Polytheism; of Theism or Atheism; of Superstition or Rationalism. With these, and their relative merits and demerits, I have nothing to do; but this it is needful for my purpose to say, that if the religion of the present differs from that of the past, it is because the theology of the present has become more scientific than that of the past; because it has not only renounced idols of wood and idols of stone, but begins to see the necessity of breaking in pieces the idols built up of books and traditions and fine-spun ecclesiastical cobwebs; and of cherishing the noblest and most human of man's emotions, by worship "for the most part of the silent sort" at the altar of the Unknown.

Such are a few of the new conceptions implanted in our minds by the improvement of natural knowledge. Men have acquired the ideas of the practically infinite extent of the universe and of its practical eternity; they are familiar with the conception that our earth is but an infinitesimal fragment of that part of the universe which can be seen; and that, nevertheless, its duration is, as compared with our standards of time, infinite.

They have further acquired the idea that man is but one of innumerable forms of life now existing on the globe, and that the present existences are but the last of an immeasurable series of predecessors. Moreover, every step they have made in natural knowledge has tended to extend and rivet in their minds the conception of a definite order of the universe—which is embodied in what are called, by an unhappy metaphor, the laws of Nature—and to narrow the range and loosen the force of men's belief in spontaneity, or in changes other than such as arise out of that definite order itself.

Whether these ideas are well or ill founded is not the question. No one can deny that they exist, and have been the inevitable outgrowth of the improvement of natural knowledge. And if so, it cannot be doubted that they are changing the form of men's most cherished and most important convictions.

And as regards the second point—the extent to which the improvement of natural knowledge has remodeled and altered what may be termed the intellectual ethics of men—what are among the moral convictions most fondly held by barbarous and semi-barbarous people.

They are the convictions that authority is the soundest basis of belief; that merit attaches to a readiness to believe, that the doubting disposition is a bad one, and skepticism a sin; that when good authority has pronounced what is to be believed, and faith has accepted it, reason has no further duty. There are many excellent persons who yet hold by these principles, and it is not my present business or intention to discuss their views. All I wish to bring clearly before your minds

is the unquestionable fact, that the improvement of natural knowledge is effected by methods which directly give the lie to all these convictions, and assume the exact reverse of each to be true.

The improver of natural knowledge absolutely refuses to acknowledge authority, as such. For him, skepticism is the highest of duties; blind faith the one unpardonable sin. And it cannot be otherwise, for every great advance in natural knowledge has involved the absolute rejection of authority, the cherishing of the keenest skepticism, the annihilation of the spirit of blind faith; and the most ardent votary of science holds his firmest convictions, not because the men he most venerates hold them; not because their verity is testified by portents and wonders; but because his experience teaches him that whenever he chooses to bring these convictions into contact with their primary source, Nature—whenever he thinks fit to test them by appealing to experiment and to observation—Nature will confirm them. The man of science has learned to believe in justification, not by faith, but by verification.

Thus, without for a moment pretending to despise the practical results of the improvement of natural knowledge, and its beneficial influence on material civilization, it must, I think, be admitted that the great ideas, some of which I have indicated, and the ethical spirit which I have endeavored to sketch, in the few moments which remained at my disposal, constitute the real and permanent significance of natural knowledge.

If these ideas be destined, as I believe they are, to be more and more firmly established as the world grows

older; if that spirit be fated, as I believe it is, to extend itself into all departments of human thought, and to become co-extensive with the range of knowledge; if, as our race approaches its maturity, it discovers, as I believe it will, that there is but one kind of knowledge and but one method of acquiring it; then we, who are still children, may justly feel it our highest duty to recognize the advisableness of improving natural knowledge, and so to aid ourselves and our successors in our course towards the noble goal which lies before mankind.

VII

A LIBERAL EDUCATION: AND WHERE TO FIND IT

[This address was delivered in January, 1868, at the opening of the South London Working Men's College of which Huxley was the Principal. It was an exposure of the lack of system in British educational methods at the time when Huxley spoke and of the mistaken aims and standards of those in control of education in England at that time. He pointed out the deficiencies of the primary school, of the "public school" (so-called) and of the universities. In the half-century and more since he exposed the many defects of the schools of his own country, most of them have been corrected, partly in consequence of the interest aroused by Huxley himself. In Great Britain, and also in the United States, a strenuous effort has been made to attain the ideal of a liberal education which he here set before us. The educational situation is far better than it was fifty years ago; but it is not yet satisfactory—and it will never be satisfactory until every one of us accepts Huxley's ideal and strives earnestly to acquire, as far as may be within our power, the firm control of mind and body, the vigorous self-mastery and clear understanding of our inexorable relation to nature and to our fellow men. It is because Huxley warns us that these acquisitions are absolutely essential that this is the most important and the most potent of all his lay sermons.]

VII

A LIBERAL EDUCATION: AND WHERE TO FIND IT

[1868]

THE business which the South London Working Men's College has undertaken is a great work; indeed, I might say that Education, with which that college proposes to grapple, is the greatest work of all those which lie ready to a man's hand just at present.

And, at length, this fact is becoming generally recognized. You cannot go anywhere without hearing a buzz of more or less confused and contradictory talk on this subject—nor can you fail to notice that, in one point at any rate, there is a very decided advance upon like discussions in former days. Nobody outside the agricultural interest now dares to say that education is a bad thing. If any representative of the once large and powerful party, which, in former days, proclaimed this opinion, still exists in the semi-fossil state, he keeps his thoughts to himself. In fact, there is a chorus of voices, almost distressing in their harmony, raised in favor of the doctrine that education is the great panacea for human

troubles, and that, if the country is not shortly to go to the dogs, everybody must be educated.

The politicians tell us, "You must educate the masses because they are going to be masters." The clergy join in the cry for education, for they affirm that the people are drifting away from church and chapel into the broadest infidelity. The manufacturers and the capitalists swell the chorus lustily. They declare that ignorance makes bad workmen; that England will soon be unable to turn out cotton goods, or steam engines, cheaper than other people; and then, Ichabod! Ichabod! the glory will be departed from us. And a few voices are lifted up in favor of the doctrine that the masses should be educated because they are men and women with unlimited capacities of being, doing, and suffering, and that it is as true now, as it ever was, that the people perish for lack of knowledge.

These members of the minority, with whom I confess I have a good deal of sympathy, are doubtful whether any of the other reasons urged in favor of the education of the people are of much value—whether, indeed, some of them are based upon either wise or noble grounds of action. They question if it be wise to tell people that you will do for them, out of fear of their power, what you have left undone, so long as your only motive was compassion for their weakness and their sorrows. And, if ignorance of everything which it is needful a ruler should know is likely to do so much harm in the governing classes of the future, why is it, they ask reasonably enough, that such ignorance in the governing classes of the past has not been viewed with equal horror?

Compare the average artisan and the average country squire, and it may be doubted if you will find a pin to choose between the two in point of ignorance, class feeling, or prejudice. It is true that the ignorance is of a different sort—that the class feeling is in favor of a different class—and that the prejudice has a distinct savor of wrong-headedness in each case—but it is questionable if the one is either a bit better or a bit worse than the other. The old protectionist theory is the doctrine of trades unions as applied by the squires, and the modern trades unionism is the doctrine of the squires applied by the artisans. Why should we be worse off under one *régime* than under the other?

Again, this skeptical minority asks the clergy to think whether it is really want of education which keeps the masses away from their ministrations—whether the most completely educated men are not as open to reproach on this score as the workmen; and whether, perchance, this may not indicate that it is not education which lies at the bottom of the matter?

Once more, these people, whom there is no pleasing, venture to doubt whether the glory which rests upon being able to undersell all the rest of the world, is a very safe kind of glory—whether we may not purchase it too dear; especially if we allow education, which ought to be directed to the making of men, to be diverted into a process of manufacturing human tools, wonderfully adroit in the exercise of some technical industry, but good for nothing else.

And finally, these people inquire whether it is the masses alone who need a reformed and improved educa-

tion. They ask whether the richest of our public schools might not well be made to supply knowledge, as well as gentlemanly habits, a strong class feeling, and eminent proficiency in cricket. They seem to think that the noble foundations of our old universities are hardly fulfilling their functions in their present posture of half clerical seminaries, half racecourses, where men are trained to win a senior wranglership, or a double-first, as horses are trained to win a cup, with as little reference to the needs of after-life in the case of a man as in that of the racer. And, while as zealous for education as the rest, they affirm that, if the education of the richer classes were such as to fit them to be the leaders and the governors of the poorer; and, if the education of the poorer classes were such as to enable them to appreciate really wise guidance and good governance, the politicians need not fear mob law, nor the clergy lament their want of flocks, nor the capitalists prognosticate the annihilation of the prosperity of the country.

Such is the diversity of opinion upon the why and the wherefore of education. And my hearers will be prepared to expect that the practical recommendations which are put forward are not less discordant. There is a loud cry for compulsory education. We English, in spite of constant experience to the contrary, preserve a touching faith in the efficacy of acts of Parliament; and I believe we should have compulsory education in the course of next session, if there were the least probability that half a dozen leading statesmen of different parties would agree what that education should be.

Some hold that education without theology is worse

than none. Others maintain, quite as strongly, that education with theology is in the same predicament. But this is certain, that those who hold the first opinion can by no means agree what theology should be taught; and that those who maintain the second are in a small minority.

At any rate "make people learn to read, write, and cipher," say a great many; and the advice is undoubtedly sensible as far as it goes. But, as has happened to me in former days, those who, in despair of getting anything better, advocate this measure, are met with the objection that it is very like making a child practice the use of a knife, fork and spoon, without giving it a particle of meat. I really don't know what reply is to be made to such an objection.

But it would be unprofitable to spend more time in disentangling, or rather in showing up the knots in, the raveled skeins of our neighbors. Much more to the purpose is it to ask if we possess any clew of our own which may guide us among these entanglements. And by way of a beginning, let us ask ourselves—What is education? Above all things, what is our ideal of a thoroughly liberal education?—of that education which, if we could begin life again, we would give ourselves—of that education which, if we could mold the fates to our own will, we would give our children? Well, I know not what may be your conceptions upon this matter, but I will tell you mine, and I hope I shall find that our views are not very discrepant.

Suppose it were perfectly certain that the life and fortune of every one of us would, one day or other, de-

pend upon his winning or losing a game of chess. Don't you think that we should all consider it to be a primary duty to learn at least the names and the moves of the pieces; to have a notion of a gambit, and a keen eye for all the means of giving and getting out of check? Do you not think that we should look with a disapprobation amounting to scorn upon the father who allowed his son, or the state which allowed its members, to grow up without knowing a pawn from a knight?

Yet it is a very plain and elementary truth that the life, the fortune, and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just and patient. But also we know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated—without haste, but without remorse.

My metaphor will remind some of you of the famous picture in which Retzsch has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing

SATAN PLAYING AT CHESS WITH MAN
FOR HIS SOUL

for love, as we say, and would rather lose than win—and I should accept it as an image of human life.

Well, what I mean by Education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of Nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws. For me, education means neither more nor less than this. Anything which professes to call itself education must be tried by this standard, and if it fails to stand the test, I will not call it education, whatever may be the force of authority, or of numbers, upon the other side.

It is important to remember that, in strictness, there is no such thing as an uneducated man. Take an extreme case. Suppose that an adult man, in the full vigor of his faculties, could be suddenly placed in the world, as Adam is said to have been, and then left to do as he best might. How long would he be left uneducated? Not five minutes. Nature would begin to teach him, through the eye, the ear, the touch, the properties of objects. Pain and pleasure would be at his elbow telling him to do this and avoid that; and by slow degrees the man would receive an education which, if narrow, would be thorough, real, and adequate to his circumstances, though there would be no extras and very few accomplishments.

And if to this solitary man entered a second Adam, or better still, an Eve, a new and greater world, that of social and moral phenomena, would be revealed. Joys

and woes, compared with which all others might seem but faint shadows, would spring from the new relations. Happiness and sorrow would take the place of the coarser monitors, pleasure and pain; but conduct would still be shaped by the observation of the natural consequences of actions; or, in other words, by the laws of the nature of man.

To every one of us the world was once as fresh and new as to Adam. And then, long before we were susceptible of any other modes of instruction, Nature took us in hand, and every minute of waking life brought its educational influence, shaping our actions into rough accordance with Nature's laws, so that we might not be ended untimely by too gross disobedience. Nor should I speak of this process of education as past for any one, be he as old as he may. For every man the world is as fresh as it was at the first day, and as full of untold novelties for him who has the eyes to see them. And Nature is still continuing her patient education of us in that great university, the universe, of which we are all members—Nature having no Test-Acts.

Those who take honors in Nature's university, who learn the laws which govern men and things and obey them, are the really great and successful men in this world. The great mass of mankind are the "Poll," who pick up just enough to get through without much discredit. Those who won't learn at all are plucked; and then you can't come up again. Nature's pluck means extermination.

Thus the question of compulsory education is settled so far as Nature is concerned. Her bill on that question

was framed and passed long ago. But, like all compulsory legislation, that of Nature is harsh and wasteful in its operation. Ignorance is visited as sharply as willful disobedience—incapacity meets with the same punishment as crime. Nature's discipline is not even a word and a blow, and the blow first; but the blow without the word. It is left to you to find out why your ears are boxed.

The object of what we commonly call education—that education in which man intervenes and which I shall distinguish as artificial education—is to make good these defects in Nature's methods; to prepare the child to receive Nature's education, neither incapably nor ignorantly, nor with willful disobedience; and to understand the preliminary symptoms of her pleasure, without waiting for the box on the ear. In short, all artificial education ought to be an anticipation of natural education. And a liberal education is an artificial education which has not only prepared a man to escape the great evils of disobedience to natural laws, but has trained him to appreciate and to seize upon the rewards, which Nature scatters with as free a hand as her penalties.

That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the

great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of Nature or of art, to hate all vileness, and to respect others as himself.

Such a one and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with Nature. He will make the best of her, and she of him. They will get on together rarely; she as his ever beneficent mother; he as her mouthpiece, her conscious self, her minister and interpreter.

Where is such an education as this to be had? Where is there any approximation to it? Has any one tried to found such an education? Looking over the length and breadth of these islands, I am afraid that all these questions must receive a negative answer. Consider our primary schools and what is taught in them. A child learns:

1. To read, write, and cipher, more or less well; but in a very large proportion of cases not so well as to take pleasure in reading, or to be able to write the commonest letter properly.

2. A quantity of dogmatic theology, of which the child, nine times out of ten, understands next to nothing.

3. Mixed up with this, so as to seem to stand or fall with it, a few of the broadest and simplest principles of morality. This, to my mind, is much as if a man of science should make the story of the fall of the apple in Newton's garden an integral part of the doctrine of

gravitation, and teach it as of equal authority with the law of the inverse squares.

4. A good deal of Jewish history and Syrian geography, and perhaps a little something about English history and the geography of the child's own country. But I doubt if there is a primary school in England in which hangs a map of the hundred in which the village lies, so that the children may be practically taught by it what a map means.

5. A certain amount of regularity, attentive obedience, respect for others: obtained by fear, if the master be incompetent or foolish; by love and reverence, if he be wise.

So far as this school course embraces a training in the theory and practice of obedience to the moral laws of nature, I gladly admit, not only that it contains a valuable educational element, but that, so far, it deals with the most valuable and important part of all education. Yet, contrast what is done in this direction with what might be done; with the time given to matters of comparatively no importance; with the absence of any attention to things of the highest moment; and one is tempted to think of Falstaff's bill and "the halfpenny worth of bread to all that quantity of sack."

Let us consider what a child thus "educated" knows, and what it does not know. Begin with the most important topic of all, morality, as the guide of conduct. The child knows well enough that some acts meet with approbation and some with disapprobation. But it has never heard that there lies in the nature of things a reason for every moral law, as cogent and as well defined as that which underlies every physical law; that stealing

and lying are just as certain to be followed by evil consequences as putting your hand in the fire, or jumping out of a garret window. Again, though the scholar may have been made acquainted, in dogmatic fashion, with the broad laws of morality, he has had no training in the application of those laws to the difficult problems which result from the complex conditions of modern civilization. Would it not be very hard to expect any one to solve a problem in conic sections who had merely been taught the axioms and definitions of mathematical science?

A workman has to bear hard labor, and perhaps privation, while he sees others rolling in wealth, and feeding their dogs with what would keep his children from starvation. Would it not be well to have helped that man to calm the natural promptings of discontent by showing him, in his youth, the necessary connection of the moral law which prohibits stealing with the stability of society—by proving to him, once for all, that it is better for his own people, better for himself, better for future generations, that he should starve than steal? If you have no foundation of knowledge, or habit of thought, to work upon, what chance have you of persuading a hungry man that a capitalist is not a thief "with a circumbendibus"? And if he honestly believes that, of what avail is it to quote the commandment against stealing, when he proposes to make the capitalist disgorge?

Again, the child learns absolutely nothing of the history or the political organization of his own country. His general impression is, that everything of much importance happened a very long while ago; and that the Queen and the gentlefolks govern the country much after

the fashion of King David and the elders and nobles of Israel—his sole models. Will you give a man with this much information a vote? In easy times he sells it for a pot of beer. Why should he not? It is of about as much use to him as a chignon, and he knows as much what to do with it, for any other purpose. In bad times, on the contrary, he applies his simple theory of government, and believes that his rulers are the cause of his sufferings—a belief which sometimes bears remarkable practical fruits.

Least of all, does the child gather from this primary "education" of ours a conception of the laws of the physical world, or of the relations of cause and effect therein. And this is the more to be lamented, as the poor are especially exposed to physical evils, and are more interested in removing them than any other class of the community. If any one is concerned in knowing the ordinary laws of mechanics one would think it is the hand-laborer, whose daily toil lies among levers and pulleys: or among the other implements of artisan work. And if any one is interested in the laws of health, it is the poor workman, whose strength is wasted by ill-prepared food, whose health is sapped by bad ventilation and bad drainage, and half whose children are massacred by disorders which might be prevented. Not only does our present primary education carefully abstain from hinting to the workmen that some of his greatest evils are traceable to mere physical agencies, which could be removed by energy, patience, and frugality; but it does worse—it renders him, so far as it can, deaf to those who could help him, and tries to substitute an Oriental submission to what is falsely

declared to be the will of God, for his natural tendency to strive after a better condition.

What wonder then, if very recently an appeal has been made to statistics for the profoundly foolish purpose of showing that education is of no good—that it diminishes neither misery nor crime among the masses of mankind? I reply, why should the thing which has been called education do either the one or the other? If I am a knave or a fool, teaching me to read and write won't make me less of either one or the other—unless somebody shows me how to put my reading and writing to wise and good purposes.

Suppose any one were to argue that medicine is of no use, because it could be proved statistically that the percentage of deaths was just the same among people who had been taught how to open a medicine chest, and among those who did not so much as know the key by sight. The argument is absurd; but it is not more preposterous than that against which I am contending. The only medicine for suffering, crime, and all the other woes of mankind, is wisdom. Teach a man to read and write, and you have put into his hands the great keys of the wisdom box. But it is quite another matter whether he ever opens the box or not. And he is as likely to poison as to cure himself, if, without guidance, he swallows the first drug that comes to hand. In these times a man may as well be purblind as unable to read—lame as unable to write. But I protest that, if I thought the alternative were a necessary one, I would rather that the children of the poor should grow up ignorant of both these mighty

arts, than that they should remain ignorant of that knowledge to which these arts are means.

It may be said that all these animadversions may apply to primary schools, but that the higher schools, at any rate, must be allowed to give a liberal education. In fact, they professedly sacrifice everything else to this object.

Let us inquire into this matter. What do the higher schools, those to which the great middle-class of the country sends its children, teach, over and above the instruction given in the primary schools? There is a little more reading and writing of English. But, for all that, every one knows that it is a rare thing to find a boy of the middle or upper classes who can read aloud decently, or who can put his thoughts on paper in clear and grammatical (to say nothing of good or elegant) language. The "ciphering" of the lower schools expands into elementary mathematics in the higher; into arithmetic, with a little algebra, a little Euclid. But I doubt if one boy in five hundred has ever heard the explanation of a rule of arithmetic, or knows his Euclid otherwise than by rote.

Of theology, the middle-class schoolboy gets rather less than poorer children, less absolutely and less relatively, because there are so many other claims upon his attention. I venture to say that, in the great majority of cases, his ideas on this subject when he leaves school are of the most shadowy and vague description, and associated with painful impressions of the weary hours spent in learning collects and catechism by heart.

Modern geography, modern history, modern literature;

the English language as a language; the whole circle of the sciences, physical, moral, and social, are even more completely ignored in the higher than in the lower schools. Up till within a few years back, a boy might have passed through any one of the great public schools with the greatest distinction and credit, and might never so much as have heard of one of the subjects I have just mentioned. He might never have heard that the earth goes round the sun; that England underwent a great revolution in 1688, and France another in 1789; that there once lived certain notable men called Chaucer, Shakespeare, Milton, Voltaire, Goethe, Schiller. The first might be a German and the last an Englishman for anything he could tell you to the contrary. And as for Science, the only idea the word would suggest to his mind would be dexterity in boxing.

I have said that this was the state of things a few years back, for the sake of the few righteous who are to be found among the educational cities of the plain. But I would not have you too sanguine about the result, if you sound the minds of the existing generation of public schoolboys on such topics as those I have mentioned.

Now let us pause to consider this wonderful state of affairs; for the time will come when Englishmen will quote it as the stock example of the stolid stupidity of their ancestors in the nineteenth century. The most thoroughly commercial people, the greatest voluntary wanderers and colonists the world has ever seen, are precisely the middle-class of this country. If there be a people which has been busy making history on the great scale for the last three hundred years—and the most

profoundly interesting history—history which, if it happened to be that of Greece or Rome, we should study with avidity—it is the English. If there be a people which, during the same period, has developed a remarkable literature, it is our own. If there be a nation whose prosperity depends absolutely and wholly upon their mastery over the forces of Nature, upon their intelligent apprehension of and obedience to the laws of the creation and distribution of wealth, and of the stable equilibrium of the forces of society, it is precisely this nation. And yet this is what these wonderful people tell their sons: "At the cost of from one to two thousand pounds of our hard-earned money, we devote twelve of the most precious years of your lives to school. There you shall toil, or be supposed to toil; but there you shall not learn one single thing of all those you will most want to know directly you leave school and enter upon the practical business of life. You will in all probability go into business, but you shall not know where, or how, any article of commerce is produced, or the difference between an export or an import, or the meaning of the word 'capital.' You will very likely settle in a colony, but you shall not know whether Tasmania is part of New South Wales, or *vice versa*.

"Very probably you may become a manufacturer, but you shall not be provided with the means of understanding the working of one of your own steam engines, or the nature of the raw products you employ; and, when you are asked to buy a patent, you shall not have the slightest means of judging whether the inventor is an impostor who

is contravening the elementary principles of science, or a man who will make you as rich as Crœsus.

"You will very likely get into the House of Commons. You will have to take your share in making laws which may prove a blessing or a curse to millions of men. But you shall not hear one word respecting the political organization of your country; the meaning of the controversy between free traders and protectionists shall never have been mentioned to you; you shall not so much as know that there are such things as economical laws.

"The mental power which will be of most importance in your daily life will be the power of seeing things as they are without regard to authority; and of drawing accurate general conclusions from particular facts. But at school and at college you shall know of no source of truth but authority; nor exercise your reasoning faculty upon anything but deduction from that which is laid down by authority.

"You will have to weary your soul with work, and many a time eat your bread in sorrow and in bitterness, and you shall not have learned to take refuge in the great source of pleasure without alloy, the serene resting place for worn human nature—the world of art."

Said I not rightly that we are a wonderful people? I am quite prepared to allow that education entirely devoted to these omitted subjects might not be a completely liberal education. But is an education which ignores them all a liberal education? Nay, is it too much to say that the education which should embrace these subjects and no others would be a real education, though an incomplete one; while an education which omits them is

really not an education at all, but a more or less useful course of intellectual gymnastics?

For what does the middle-class school put in the place of all these things which are left out? It substitutes what is usually comprised under the compendious title of the "classics"—that is to say, the languages, the literature, and the history of the ancient Greeks and Romans, and the geography of so much of the world as was known to these two great nations of antiquity. Now, do not expect me to depreciate the earnest and enlightened pursuit of classical learning. I have not the least desire to speak ill of such occupations, nor any sympathy with them who run them down. On the contrary, if my opportunities had lain in that direction, there is no investigation into which I could have thrown myself with greater delight than that of antiquity.

What science can present greater attractions than philology? How can a lover of literary excellence fail to rejoice in the ancient masterpieces? And with what consistency could I, whose business lies so much in the attempt to decipher the past, and to build up intelligible forms out of the scattered fragments of long-extinct beings, fail to take a sympathetic, though an unlearned, interest in the labors of a Niebuhr, a Gibbon, or a Grote? Classical history is a great section of the paleontology of man; and I have the same double respect for it as for other kinds of paleontology—that is to say, a respect for the facts which it establishes, as for all facts, and a still greater respect for it as a preparation for the discovery of a law of progress.

But if the classics were taught as they might be taught —if boys and girls were instructed in Greek and Latin, not merely as languages, but as illustrations of philological science; if a vivid picture of life on the shores of the Mediterranean two thousand years ago were imprinted on the minds of scholars; if ancient history were taught, not as a weary series of feuds and fights, but traced to its causes in such men placed under such conditions; if, lastly, the study of the classical books were followed in such a manner as to impress boys with their beauties, and with the grand simplicity of their statement of the everlasting problems of human life, instead of with their verbal and grammatical peculiarities, I still think it as little proper that they should form the basis of a liberal education for our contemporaries, as I should think it fitting to make that sort of paleontology with which I am familiar the backbone of modern education.

It is wonderful how close a parallel to classical training could be made out of that paleontology to which I refer. In the first place, I could get up an osteological primer so arid, so pedantic in its terminology, so altogether distasteful to the youthful mind, as to beat the recent famous production of the head-masters out of the field in all these excellences. Next, I could exercise my boys upon easy fossils, and bring out all their powers of memory and all their ingenuity in the application of my osteogrammatical rules to the interpretation, or construing, of those fragments. To those who had reached the higher classes, I might supply odd bones to be built up into animals, giving great honor and reward to him who succeeded in fabricating monsters most entirely in ac-

cordance with the rules. That would answer to verse making and essay writing in the dead languages.

To be sure, if a great comparative anatomist were to look at these fabrications he might shake his head, or laugh. But what then? Would such a catastrophe destroy the parallel? What, think you, would Cicero, or Horace, say to the production of the best sixth form going? And would not Terence stop his ears and run out if he could be present at an English performance of his own plays? Would *Hamlet,* in the mouths of a set of French actors, who should insist on pronouncing English after the fashion of their own tongue, be more hideously ridiculous?

But it will be said that I am forgetting the beauty, and the human interest, which appertain to classical studies. To this I reply that it is only a very strong man who can appreciate the charms of a landscape as he is toiling up a steep hill, along a bad road. What with short-windedness, stones, ruts, and a pervading sense of the wisdom of rest and be thankful, most of us have little enough sense of the beautiful under these circumstances. The ordinary schoolboy is precisely in this case. He finds Parnassus uncommonly steep, and there is no chance of his having much time or inclination to look about him till he gets to the top. And nine times out of ten he does not get to the top.

But if this be a fair picture of the results of classical teaching at its best—and I gather from those who have authority to speak on such matters that it is so—what is to be said of classical teaching at its worst, or, in other words, of the classics of our ordinary middle-class

schools?* I will tell you. It means getting up endless forms and rules by heart. It means turning Latin and Greek into English, for the mere sake of being able to do it, and without the smallest regard to the worth, or worthlessness, of the author read. It means the learning of innumerable, not always decent, fables in such a shape that the meaning they once had is dried up into utter trash; and the only impression left upon a boy's mind is, that the people who believed such things must have been the greatest idiots the world ever saw. And it means finally, that after a dozen years spent at this kind of work, the sufferer shall be incompetent to interpret a passage in an author he has not already got up; that he shall loathe the sight of a Greek or Latin book; and that he shall never open, or think of, a classical writer again until, wonderful to relate, he insists upon submitting his sons to the same process.

These be your gods, O Israel! For the sake of this net result (and respectability) the British father denies his children all the knowledge they might turn to account in life, not merely for the achievement of vulgar success, but for guidance in the great crises of human existence. This is the stone he offers to those whom he is bound by the strongest and tenderest ties to feed with bread.

If primary and secondary education are in this unsatisfactory state, what is to be said to the universities? This is an awful subject, and one I almost fear to touch

* For a justification of what is here said about these schools, see that valuable book, *Essays on a Liberal Education, passim.*

with my unhallowed hands; but I can tell you what those say who have authority to speak.

The Rector of Lincoln College, in his lately published valuable "Suggestions for Academical Organization with especial reference to Oxford," tells us (p. 127):—

"The colleges were, in their origin, endowments, not for the elements of a general liberal education, but for the prolonged study of special and professional faculties by men of riper age. The universities embraced both these objects. The colleges, while they incidentally aided in elementary education, were specially devoted to the highest learning. . . .

"This was the theory of the middle-age university and the design of collegiate foundations in their origin. Time and circumstances have brought about a total change. The colleges no longer promote the researches of science, or direct professional study. Here and there college walls may shelter an occasional student, but not in larger proportions than may be found in private life. Elementary teaching of youths under twenty is now the only function performed by the university, and almost the only object of college endowments. Colleges were homes for the life-study of the highest and most abstruse parts of knowledge. They have become boarding schools in which the elements of the learned languages are taught to youths."

If Mr. Pattison's high position, and his obvious love and respect for his university, be insufficient to convince the outside world that language so severe is yet no more than just, the authority of the Commissioners who re-

ported on the University of Oxford in 1850 is open to no challenge. Yet they write:—

"It is generally acknowledged that both Oxford and the country at large suffer greatly from the absence of a body of learned men devoting their lives to the cultivation of science, and to the direction of academical education.

"The fact that so few books of profound research emanate from the University of Oxford, materially impairs its character as a seat of learning, and consequently its hold on the respect of the nation."

Cambridge can claim no exemption from the reproaches addressed to Oxford. And thus there seems no escape from the admission that what we fondly call our great seats of learning are simply "boarding schools" for bigger boys; that learned men are not more numerous in them than out of them; that the advancement of knowledge is not the object of fellows of colleges; that, in the philosophic calm and meditative stillness of their green-swarded courts, philosophy does not thrive, and meditation bears few fruits.

It is my great good fortune to reckon amongst my friends resident members of both universities, who are men of learning and research, zealous cultivators of science, keeping before their minds a noble ideal of a university, and doing their best to make that ideal a reality; and to me they would necessarily typify the universities, did not the authoritative statements I have quoted compel me to believe that they are exceptional, and not representative men. Indeed, upon calm consideration, several circumstances lead me to think that the

Rector of Lincoln College and the Commissioners cannot be far wrong.

I believe there can be no doubt that the foreigner who should wish to become acquainted with the scientific, or the literary, activity of modern England, would simply lose his time and his pains if he visited our universities with that object.

And, as for works of profound research on any subject, and above all, in that classical lore for which the universities profess to sacrifice almost everything else, why, a third-rate, poverty-stricken German university turns out more produce of that kind in one year than our vast and wealthy foundations elaborate in ten.

Ask the man who is investigating any question, profoundly and thoroughly—be it historical, philosophical, philological, physical, literary, or theological; who is trying to make himself master of any abstract subject (except perhaps, political economy and geology, both of which are intensely Anglican sciences), whether he is not compelled to read half a dozen times as many German as English books? And whether, of these English books, more than one in ten is the work of a fellow of a college, or a professor of an English university?

Is this from any lack of power in the English as compared with the German mind? The countrymen of Grote and of Mill, of Faraday, of Robert Brown, of Lyell, and of Darwin, to go no further back than the contemporaries of men of middle age, can afford to smile at such a suggestion. England can show now, as she has been able to show in every generation since civilization spread over the West, individual men who hold their own against the

world, and keep alive the old tradition of her intellectual eminence.

But in the majority of cases, these men are what they are in virtue of their native intellectual force, and of a strength of character which will not recognize impediments. They are not trained in the courts of the Temple of Science, but storm the walls of that edifice in all sorts of irregular ways, and with much loss of time and power, in order to obtain their legitimate positions.

Our universities not only do not encourage such men; do not offer them positions, in which it should be their highest duty to do thoroughly that which they are most capable of doing; but, as far as possible, university training shuts out of the minds of those among them, who are subjected to it, the prospect that there is anything in the world for which they are specially fitted. Imagine the success of the attempt to still the intellectual hunger of any of the men I have mentioned, by putting before him, as the object of existence, the successful mimicry of the measure of a Greek song, or the roll of Ciceronian prose! Imagine how much success would be likely to attend the attempt to persuade such men that the education which leads to perfection in such elegances is alone to be called culture; while the facts of history, the process of thought, the conditions of moral and social existence, and the laws of physical nature are left to be dealt with as they may by outside barbarians!

It is not thus that the German universities, from being beneath notice a century ago, have become what they are now—the most intensely cultivated and the most productive intellectual corporations the world has ever seen.

The student who repairs to them sees in the list of classes and of professors a fair picture of the world of knowledge. Whatever he needs to know there is some one ready to teach him, some one competent to discipline him in the way of learning; whatever his special bent, let him but be able and diligent, and in due time he shall find distinction and a career. Among his professors, he sees men whose names are known and revered throughout the civilized world; and their living example infects him with a noble ambition, and a love for the spirit of work.

The Germans dominate the intellectual world by virtue of the same simple secret as that which made Napoleon the master of old Europe. They have declared *la carrière ouverte aux talents,* and every Bursch marches with a professor's gown in his knapsack. Let him become a great scholar, or man of science, and ministers will compete for his services. In Germany they do not leave the chance of his holding the office he would render illustrious to the tender mercies of a hot canvass, and the final wisdom of a mob of country parsons.

In short, in Germany, the universities are exactly what the Rector of Lincoln and the Commissioners tell us the English universities are not; that is to say, corporations "of learned men devoting their lives to the cultivation of science, and the direction of academical education." They are not "boarding schools for youths," nor clerical seminaries; but institutions for the higher culture of men, in which the theological faculty is of no more importance or prominence than the rest; and which are truly "universities," since they strive to represent and embody the

totality of human knowledge, and to find room for all forms of intellectual activity.

Many zealous and clear-headed reformers like Mr. Pattison succeeded in their noble endeavors to shape our universities towards some such ideal as this, without losing what is valuable and distinctive in their social tone! But until they have succeeded, a liberal education will be no more obtainable in our Oxford and Cambridge Universities than in our public schools.

If I am justified in my conception of the ideal of a liberal education, and if what I have said about the existing educational institutions of the country is also true, it is clear that the two have no sort of relation to one another; that the best of our schools and the most complete of our university trainings give but a narrow, one-sided, and essentially illiberal education—while the worst give what is really next to no education at all. The South London Working-Men's College could not copy any of these institutions if it would; I am bold enough to express the conviction that it ought not if it could.

For what is wanted is the reality and not the mere name of a liberal education; and this College must steadily set before itself the ambition to be able to give that education sooner or later. At present we are but beginning, sharpening our educational tools, as it were, and, except a modicum of physical science, we are not able to offer much more than is to be found in an ordinary school.

Moral and social science—one of the greatest and most fruitful of our future classes, I hope—at present lacks only one thing in our program, and that is a teacher. A

considerable want, no doubt; but it must be recollected that it is much better to want a teacher than to want the desire to learn.

Further, we need what, for want of a better name, I must call Physical Geography. What I mean is that which the Germans call *Erdkunde*. It is a description of the earth, of its place and relation to other bodies; of its general structure, and of its great features—winds, tides, mountains, plains: of the chief forms of the vegetable and animal worlds, of the varieties of man. It is the peg upon which the greatest quantity of useful and entertaining scientific information can be suspended.

Literature is not upon the College program; but I hope some day to see it there. For literature is the greatest of all sources of refined pleasure, and one of the great uses of a liberal education is to enable us to enjoy that pleasure. There is scope enough for the purposes of liberal education in the study of the rich treasures of our own language alone. All that is needed is direction, and the cultivation of a refined taste by attention to sound criticism. But there is no reason why French and German should not be mastered sufficiently to read what is worth reading in those languages with pleasure and with profit.

And finally, by and by, we must have History; treated not as a succession of battles and dynasties; not as a series of biographies; not as evidence that Providence has always been on the side of either Whigs or Tories; but as the development of man in times past, and in other conditions than our own.

But, as it is one of the principles of our College to be

self-supporting, the public must lead, and we must follow, in these matters. If my hearers take to heart what I have said about liberal education, they will desire these things, and I doubt not we shall be able to supply them. But we must wait till the demand is made.

VIII

SCIENCE AND CULTURE

[This address was delivered in Birmingham in 1880 at the opening of Sir Josiah Mason's Science College, one of the earliest technical schools to be established in England. Apparently its founder intended it to be merely a vocational school to fit men for service in the factories of Birmingham. But Huxley, with a tact equal to his courtesy, made a plea for a more liberal training and for the inclusion of broadening studies, the necessity for which the benevolent founder had failed to see. A man of science himself, Huxley was also a man of letters, with a keen appreciation of literature, an abiding affection for it, and a firm conviction of its utility in opening the mind of the immature. He had no more sympathy with those who held that an acquaintance with science was all-sufficient than he had with those who held that a knowledge of literature was all-sufficient. And this address may therefore be regarded as a postscript to that on "A Liberal Education" which he had delivered twelve years earlier.]

VIII

SCIENCE AND CULTURE

[1880]

Six years ago, as some of my present hearers may remember, I had the privilege of addressing a large assemblage of the inhabitants of this city, who had gathered together to do honor to the memory of their famous townsman, Joseph Priestley; and, if any satisfaction attaches to posthumous glory, we may hope that the names of the burnt-out philosopher were then finally appeased.

No man, however, who is endowed with a fair share of common sense, and not more than a fair share of vanity, will identify either contemporary or posthumous fame with the highest good; and Priestley's life leaves no doubt that he, at any rate, set a much higher value upon the advancement of knowledge, and the promotion of that freedom of thought which is at once the cause and the consequence of intellectual progress.

Hence I am disposed to think that, if Priestley could be among us to-day, the occasion of our meeting would afford him even greater pleasure than the proceedings which celebrated the centenary of his chief discovery. The kindly heart would be moved, the high sense of social duty would be satisfied, by the spectacle of well-earned

wealth neither squandered in tawdry luxury and vainglorious show, nor scattered with the careless charity which blesses neither him that gives nor him that takes, but expended in the execution of a well-considered plan for the aid of present and future generations of those who are willing to help themselves.

We shall all be of one mind thus far. But it is needful to share Priestley's keen interest in physical science; and to have learned, as he had learned, the value of scientific training in fields of inquiry apparently far remote from physical science; in order to appreciate, as he would have appreciated, the value of the noble gift which Sir Josiah Mason has bestowed upon the inhabitants of the Midland district.

For us children of the nineteenth century, however, the establishment of a college under the conditions of Sir Josiah Mason's Trust, has a significance apart from any which it could have possessed a hundred years ago. It appears to be an indication that we are reaching the crisis of the battle, or rather of the long series of battles, which have been fought over education in a campaign which began long before Priestley's time, and will probably not be finished just yet.

In the last century, the combatants were the champions of ancient literature on the one side, and those of modern literature on the other; but, some thirty years * ago, the contest became complicated by the appearance of a

* The advocacy of the introduction of physical science into general education by George Combe and others commenced a good deal earlier; but the movement had acquired hardly any practical force before the time to which I refer.

third army, ranged round the banner of Physical Science.

I am not aware that any one has authority to speak in the name of this new host. For it must be admitted to be somewhat of a guerilla force, composed largely of irregulars, each of whom fights pretty much for his own hand. But the impressions of a full private, who has seen a good deal of service in the ranks, respecting the present position of affairs and the conditions of a permanent peace, may not be devoid of interest; and I do not know that I could make a better use of the present opportunity than by laying them before you.

From the time that the first suggestion to introduce physical science into ordinary education was timidly whispered, until now, the advocates of scientific education have met with opposition of two kinds. On the one hand, they have been pooh-poohed by the men of business who pride themselves on being the representatives of practicality; while, on the other hand, they have been ex-communicated by the classical scholars; in their capacity of Levites in charge of the ark of culture and monopolists of liberal education.

The practical men believed that the idol whom they worship—rule of thumb—has been the source of the past prosperity, and will suffice for the future welfare of the arts and manufactures. They were of opinion that science is speculative rubbish; that theory and practice have nothing to do with one another; and that the scientific habit of mind is an impediment, rather than an aid, in the conduct of ordinary affairs.

I have used the past tense in speaking of the practical men—for although they were very formidable thirty years ago, I am not sure that the pure species has not been extirpated. In fact, so far as mere argument goes, they have been subjected to such a *feu d'enfer* that it is a miracle if any have escaped. But I have remarked that your typical practical man has an unexpected resemblance to one of Milton's angels. His spiritual wounds, such as are inflicted by logical weapons, may be as deep as a well and as wide as a church door, but beyond shedding a few drops of ichor, celestial or otherwise, he is no whit the worse. So, if any of these opponents be left, I will not waste time in vain repetition of the demonstrative evidence of the practical value of science; but knowing that a parable will sometimes penetrate where syllogisms fail to effect an entrance, I will offer a story for their consideration.

Once upon a time, a boy with nothing to depend upon but his own vigorous nature, was thrown into the thick of the struggle for existence in the midst of a great manufacturing population. He seems to have had a hard fight, inasmuch as, by the time he was thirty years of age, his total disposable funds amounted to twenty pounds. Nevertheless, middle life found him giving proof of his comprehension of the practical problems he had been roughly called upon to solve, by a career of remarkable prosperity.

Finally, having reached old age with its well-earned surroundings of "honor, troops of friends," the hero of my story bethought himself of those who were making a

like start in life, and how he could stretch out a helping hand to them.

After long and anxious reflection this successful practical man of business could devise nothing better than to provide them with the means of obtaining "sound, extensive, and practical scientific knowledge." And he devoted a large part of his wealth and five years of incessant work to this end.

I need not point the moral of a tale which, as the solid and spacious fabric of the Scientific College assures us, is no fable, nor can anything which I could say intensify the force of this practical answer to practical objections.

We may take it for granted then, that, in the opinion of those best qualified to judge, the diffusion of thorough scientific education is an absolutely essential condition of industrial progress; and that the College which has been opened to-day will confer an inestimable boon upon those whose livelihood is to be gained by the practice of the arts and manufactures of the district.

The only question worth discussion is, whether the conditions, under which the work of the College is to be carried out, are such as to give it the best possible chance of achieving permanent success.

Sir Josiah Mason, without doubt most wisely, has left very large freedom of action to the trustees, to whom he proposes ultimately to commit the administration of the College, so that they may be able to adjust its arrangements in accordance with the changing conditions of the future. But with respect to three points, he has

laid most explicit injunctions upon both administrators and teachers.

Party politics are forbidden to enter into the minds of either so far as the work of the College is concerned; theology is as sternly banished from its precincts; and finally, it is especially declared that the College shall make no provision for "mere literary instruction and education."

It does not concern me at present to dwell upon the first two injunctions any longer than may be needful to express my full conviction of their wisdom. But the third prohibition brings us face to face with those other opponents of scientific education, who are by no means in the moribund condition of the practical man, but alive, alert, and formidable.

It is not impossible that we shall hear this express exclusion of "literary instruction and education" from a College which, nevertheless, professes to give a high and efficient education, sharply criticized. Certainly the time was that the Levites of culture would have sounded their trumpets against its walls as against an educational Jericho.

How often have we not been told that the study of physical science is incompetent to confer culture; that it touches none of the higher problems of life; and what is worse, that the continual devotion to scientific studies tends to generate a narrow and bigoted belief in the applicability of scientific methods to the search after truth of all kinds! How frequently one has reason to observe that no reply to a troublesome argument tells so well as calling its author a "mere scientific specialist." And, as

I am afraid it is not permissible to speak of this form of opposition to scientific education in the past tense, may we not expect to be told that this, not only omission, but prohibition, of "mere literary instruction and education" is a patent example of scientific narrow-mindedness?

I am not acquainted with Sir Josiah Mason's reasons for the action which he has taken; but if, as I apprehend is the case, he refers to the ordinary classical course of our schools and universities by the name of "mere literary instruction and education," I venture to offer sundry reasons of my own in support of that action.

For I hold very strongly by two convictions—The first is, that neither the discipline nor the subject-matter of classical education is of such direct value to the student of physical science as to justify the expenditure of valuable time upon either; and the second is, that for the purpose of attaining real culture, an exclusively scientific education is at least as effectual as an exclusively literary education.

I need hardly point out to you that these opinions, especially the latter, are diametrically opposed to those of the great majority of educated Englishmen, influenced as they are by school and university traditions. In their belief, culture is obtainable only by a liberal education; and a liberal education is synonymous, not merely with education and instruction in literature, but in one particular form of literature, namely, that of Greek and Roman antiquity. They hold that the man who has learned Latin and Greek, however little, is educated; while he who is versed in other branches of knowledge, however deeply, is a more or less respectable specialist,

not admissible into the cultured caste. The stamp of the educated man, the University degree, is not for him.

I am too well acquainted with the generous catholicity of spirit, the true sympathy with scientific thought, which pervades the writings of our chief apostle of culture to identify him with these opinions; and yet one may cull from one and another of those epistles to the Philistines, which so much delight all who do not answer to that name, sentences which lend them some support.

Mr. Arnold tells us that the meaning of culture is "to know the best that has been thought and said in the world." It is the criticism of life contained in literature. That criticism regards "Europe as being, for intellectual and spiritual purposes, one great confederation, bound to a joint action and working to a common result; and whose members have, for their common outfit, a knowledge of Greek, Roman, and Eastern antiquity, and of one another. Special, local, and temporary advantages being put out of account, that modern nation will in the intellectual and spiritual sphere make most progress which most thoroughly carries out this program. And what is that but saying that we too, all of us, as individuals, the more thoroughly we carry it out, shall make the more progress?" *

We have here to deal with two distinct propositions. The first, that a criticism of life is the essence of culture; the second, that literature contains the materials which suffice for the construction of such criticism.

I think that we must all assent to the first proposition. For culture certainly means something quite different

* *Essays on Criticism*, p. 37.

from learning or technical skill. It implies the possession of an ideal, and the habit of critically estimating the value of things by comparison with a theoretic standard. Perfect culture should supply a complete theory of life, based upon a clear knowledge alike of its possibilities and of its limitations.

But we may agree to all this, and yet strongly dissent from the assumption that literature alone is competent to supply this knowledge. After having learned all that Greek, Roman, and Eastern antiquity have thought and said, and all that modern literature have to tell us, it is not self-evident that we have laid a sufficiently broad and deep foundation for that criticism of life which constitutes culture.

Indeed, to any one acquainted with the scope of physical science, it is not at all evident. Considering progress only in the "intellectual and spiritual sphere," I find myself wholly unable to admit that either nations or individuals will really advance, if their common outfit draws nothing from the stores of physical science. I should say that an army, without weapons of precision and with no particular base of operations, might more hopefully enter upon a campaign on the Rhine, than a man, devoid of a knowledge of what physical science has done in the last century, upon a criticism of life.

When a biologist meets with an anomaly, he instinctively turns to the study of development to clear it up. The rationale of contradictory opinions may with equal confidence be sought in history.

It is, happily, no new thing that Englishmen should

employ their wealth in building and endowing institutions for educational purposes. But five or six hundred years ago, deeds of foundation expressed or implied conditions as nearly as possible contrary to those which have been thought expedient by Sir Josiah Mason. That is to say, physical science was practically ignored, while a certain literary training was enjoined as a means to the acquirement of knowledge which was essentially theological.

The reason of this singular contradiction between the actions of men alike animated by a strong and disinterested desire to promote the welfare of their fellows, is easily discovered.

At that time in fact, if any one desired knowledge beyond such as could be obtained by his own observation, or by common conversation, his first necessity was to learn the Latin language, inasmuch as all the higher knowledge of the western world was contained in works written in that language. Hence, Latin grammar, with logic and rhetoric, studied through Latin, were the fundamentals of education; with respect to the substance of the knowledge imparted through this channel, the Jewish and Christian Scriptures, as interpreted and supplemented by the Romish Church, were held to contain a complete and infallibly true body of information.

Theological dicta were, to the thinkers of those days, that which the axioms and definitions of Euclid are to the geometers of these. The business of the philosophers of the Middle Ages was to deduce from the data furnished by the theologians, conclusions in accordance with ecclesiastical decrees. They were allowed the high privilege

of showing, by logical process, how and why that which the Church said was true, must be true. And if their demonstrations fell short of or exceeded this limit, the Church was maternally ready to check their aberrations; if need were by the help of the secular arm.

Between the two, our ancestors were furnished with a compact and complete criticism of life. They were told how the world began and how it would end; they learned that all material existence was but a base and insignificant blot upon the fair face of the spiritual world, and that nature was, to all intents and purposes, the playground of the devil; they learned that the earth is the center of the visible universe, and that man is the cynosure of things terrestrial; and more especially was it inculcated that the course of nature had no fixed order, but that it could be, and constantly was, altered by the agency of innumerable spiritual beings, good and bad, according as they were moved by the deeds and prayers of men. The sum and substance of the whole doctrine was to produce the conviction that the only thing really worth knowing in this world was how to secure that place in a better which, under certain conditions, the Church promised.

Our ancestors had a living belief in this theory of life, and acted upon it in their dealings with education, as in all other matters. Culture meant saintliness—after the fashion of the saints of those days; the education that led to it was, of necessity, theological; and the way to theology lay through Latin.

That the study of nature—further than was requisite for the satisfaction of everyday wants—should have any

bearing on human life was far from the thoughts of men thus trained. Indeed, as nature had been cursed for man's sake, it was an obvious conclusion that those who meddled with nature were likely to come into pretty close contact with Satan. And, if any born scientific investigator followed his instincts, he might safely reckon upon earning the reputation, and probably upon suffering the fate, of a sorcerer.

Had the western world been left to itself in Chinese isolation, there is no saying how long this state of things might have endured. But, happily, it was not left to itself. Even earlier than the thirteenth century the development of Moorish civilization in Spain and the great movement of the Crusades had introduced the leaven which, from that day to this, has never ceased to work. At first, through the intermediation of Arabic translations, afterwards by the study of the originals, the western nations of Europe became acquainted with the writings of the ancient philosophers and poets, and, in time, with the whole of the vast literature of antiquity.

Whatever there was of high intellectual aspiration or dominant capacity in Italy, France, Germany, and England, spent itself for centuries in taking possession of the rich inheritance left by the dead civilizations of Greece and Rome. Marvelously aided by the invention of printing, classical learning spread and flourished. Those who possessed it prided themselves on having attained the highest culture then within the reach of mankind.

And justly. For, saving Dante on his solitary pinnacle, there was no figure in modern literature at the time of the Renaissance to compare with the men of

antiquity; there was no art to compete with their sculpture; there was no physical science but that which Greece had created. Above all, there was no other example of perfect intellectual freedom—of the unhesitating acceptance of reason as the sole guide to truth and the supreme arbiter of conduct.

The new learning necessarily soon exerted a profound influence upon education. The language of the monks and schoolmen seemed little better than gibberish to scholars fresh from Virgil and Cicero, and the study of Latin was placed upon a new foundation. Moreover, Latin itself ceased to afford the sole key to knowledge. The student who sought the highest thought of antiquity, found only a second-hand reflection of it in Roman literature, and turned his face to the full light of the Greeks. And after a battle, not altogether dissimilar to that which is at present being fought over the teaching of physical science, the study of Greek was recognized as an essential element of all higher education.

Then the Humanists, as they were called, won the day; and the great reform which they effected was of incalculable service to mankind. But the Nemesis of all reformers is finality; and the reformers of education, like those of religion, fell into the profound, however common, error of mistaking the beginning for the end of the work of reformation.

The representatives of the Humanists in the nineteenth century take their stand upon classical education as the sole avenue to culture, as firmly as if we were still in the age of Renaissance. Yet, sure, the present intellectual relations of the modern and the ancient worlds

are profoundly different from those which obtained three centuries ago. Leaving aside the existence of a great and characteristically modern literature, of modern painting, and, especially, of modern music, there is one feature of the present state of the civilized world which separates it more widely from the Renaissance, than the Renaissance was separated from the middle ages.

This distinctive character of our own times lies in the vast and constantly increasing part which is played by natural knowledge. Not only is our daily life shaped by it, not only does the prosperity of millions of men depend upon it, but our whole theory of life has long been influenced, consciously or unconsciously, by the general conceptions of the universe, which have been forced upon us by physical science.

In fact, the most elementary acquaintance with the results of scientific investigation shows us that they offer a broad and striking contradiction to the opinion so implicitly credited and taught in the middle ages.

The notions of the beginning and the end of the world entertained by our forefathers are not longer credible. It is very certain that the earth is not the chief body in the material universe, and that the world is not subordinated to man's use. It is even more certain that nature is the expression of a definite order with which nothing interferes, and that the chief business of mankind is to learn that order and govern themselves accordingly. Moreover this scientific "criticism of life" presents itself to us with different credentials from any other. It appeals not to authority, nor to what anybody may have thought or said, but to nature. It admits that all our

interpretations of natural fact are more or less imperfect and symbolic, and bids the learner seek for truth not among words but among things. It warns us that the assertion which outstrips evidence is not only a blunder but a crime.

The purely classical education advocated by the representatives of the Humanists in our day gives no inkling of all this. A man may be a better scholar than Erasmus, and know no more of the chief causes of the present intellectual fermentation than Erasmus did. Scholarly and pious persons, worthy of all respect, favor us with allocutions upon the sadness of the antagonism of science to their medieval way of thinking, which betray an ignorance of the first principles of scientific investigation, an incapacity for understanding what a man of science means by veracity, and an unconsciousness of the weight of established scientific truths, which is almost comical.

There is no great force in the *tu quoque* argument, or else the advocates of scientific education might fairly enough retort upon the modern Humanists that they may be learned specialists, but that they possess no such foundation for a criticism of life as deserves the name of culture. And indeed, if we were disposed to be cruel, we might urge that the Humanists have brought this reproach upon themselves, not because they are too full of the spirit of the ancient Greek, but because they lack it.

The period of the Renaissance is commonly called that of the "Revival of Letters," as if the influences then brought to bear upon the mind of Western Europe had

been wholly exhausted in the field of literature. I think it is very commonly forgotten that the revival of science, effected by the same agency, although less conspicuous, was not less momentous.

In fact, the few and scattered students of nature of that day picked up the clue to her secrets exactly as it fell from the hands of the Greeks a thousand years before. The foundations of mathematics were so well laid by them, that our children learn their geometry from a book written for the schools of Alexandria two thousand years ago. Modern astronomy is the natural continuation and development of the work of Hipparchus and of Ptolemy; modern physics of that of Democritus and Archimedes; it was long before modern biological science outgrew the knowledge bequeathed to us by Aristotle, by Theophrastus, and by Galen.

We cannot know all the best thoughts and sayings of the Greeks unless we know what they thought about natural phenomena. We cannot fully apprehend their criticism of life unless we understand the extent to which that criticism was affected by scientific conceptions. We falsely pretend to be the inheritors of their culture, unless we are penetrated, as the best minds among them were, with an unhesitating faith that the free employment of reason, in accordance with scientific method, is the sole method of reaching truth.

Thus I venture to think that the pretensions of our modern Humanists to the possession of the monopoly of culture and to the exclusive inheritance of the spirit of antiquity must be abated, if not abandoned. But I should be very sorry that anything I have said should

be taken to imply a desire on my part to depreciate the value of classical education, as it might be and as it sometimes is. The native capacities of mankind vary no less than their opportunities; and while culture is one, the road by which one man may best reach it is widely different from that which is most advantageous to another. Again, while scientific education is yet inchoate and tentative, classical education is thoroughly well organized upon the practical experience of generations of teachers. So that, given ample time for learning and estimation for ordinary life, or for a literary career, I do not think that a young Englishman in search of culture can do better than follow the course usually marked out for him, supplementing its deficiencies by his own efforts.

But for those who mean to make science their serious occupation; or who intend to follow the profession of medicine; or who have to enter early upon the business of life; for all these, in my opinion, classical education is a mistake; and it is for this reason that I am glad to see "mere literary education and instruction" shut out from the curriculum of Sir Josiah Mason's College, seeing that its inclusion would probably lead to the introduction of the ordinary smattering of Latin and Greek.

Nevertheless, I am the last person to question the importance of genuine literary education, or to suppose that intellectual culture can be complete without it. An exclusively scientific training will bring about a mental twist as surely as an exclusively literary training. The value of the cargo does not compensate for a ship's being out of trim; and I should be very sorry to think that the

Scientific College would turn out none but lopsided men.

There is no need, however, that such a catastrophe should happen. Instruction in English, French, and German is provided, and thus the three greatest literatures of the modern world are made accessible to the student.

French and German, and especially the latter language, are absolutely indispensable to those who desire full knowledge in any department of science. But even supposing that the knowledge of these languages acquired is not more than sufficient for purely scientific purposes, every Englishman has, in his native tongue, an almost perfect instrument of literary expression; and, in his own literature, models of every kind of literary excellence. If an Englishman cannot get literary culture out of his Bible, his Shakespeare, his Milton, neither, in my belief, will the profoundest study of Homer and Sophocles, Virgil and Horace, give it to him.

Thus, since the constitution of the College makes sufficient provision for literary as well as for scientific education, and since artistic instruction is also contemplated, it seems to me that a fairly complete culture is offered to all who are willing to take advantage of it.

But I am not sure that at this point the "practical" man, scotched but not slain, may ask what all this talk about culture has to do with an Institution, the object of which is defined to be "to promote the prosperity of the manufactures and the industry of the country." He may suggest that what is wanted for this end is not culture, nor even a purely scientific discipline, but simply a knowledge of applied science.

I often wish that this phrase, "applied science," had never been invented. For it suggests that there is a sort of scientific knowledge of direct practical use, which can be studied apart from another sort of scientific knowledge, which is of no practical utility, and which is termed "pure science." But there is no more complete fallacy than this. What people call applied science is nothing but the application of pure science to particular classes of problems. It consists of deductions from those general principles, established by reasoning and observation, which constitute pure science. No one can safely make these deductions until he has a firm grasp of the principles; and he can obtain that grasp only by personal experience of the operations of observation and of reasoning on which they are founded.

Almost all the processes employed in the arts and manufactures fall within the range either of physics or of chemistry. In order to improve them, one must thoroughly understand them; and no one has a chance of really understanding them, unless he has obtained that mastery of principles and that habit of dealing with facts, which is given by long-continued and well-directed purely scientific training in the physical and the chemical laboratory. So that there really is no question as to the necessity of purely scientific discipline, even if the work of the College were limited by the narrowest interpretation of its stated aims.

And, as to the desirableness of a wider culture than that yielded by science alone, it is to be recollected that the improvement of manufacturing processes is only one of the conditions which contribute to the prosperity of

industry. Industry is a means and not an end; and mankind work only to get something which they want. What that something is depends partly on their innate, and partly on their acquired, desires.

If the wealth resulting from prosperous industry is to be spent upon the gratification of unworthy desires, if the increasing perfection of manufacturing processes is to be accompanied by an increasing debasement of those who carry them on, I do not see the good of industry and prosperity.

Now it is perfectly true that men's views of what is desirable depend upon their characters; and that the innate proclivities to which we give that name are not touched by any amount of instruction. But it does not follow that even mere intellectual education may not, to an indefinite extent, modify the practical manifestation of the characters of men in their actions, by supplying them with motives unknown to the ignorant. A pleasure-loving character will have pleasure of some sort; but, if you give him the choice, he may prefer pleasures which do not degrade him to those which do. And this choice is offered to every man, who possesses in literary or artistic culture a never-failing source of pleasures, which are neither withered by age, nor staled by custom, nor embittered in the recollection by the pangs of self-reproach.

If the Institution opened to-day fulfils the intention of its founder, the picked intelligences among all classes of the population of this district will pass through it. No child born in Birmingham, henceforward, if he have the capacity to profit by the opportunities offered to him,

first in the primary and other schools, and afterwards in the Scientific College, need fail to obtain, not merely the instruction, but the culture most appropriate to the conditions of his life.

Within these walls, the future employer and the future artisan may sojourn together for a while, and carry through all their lives the stamp of the influences then brought to bear upon them. Hence, it is not beside the mark to remind you, that the prosperity of industry depends not merely upon the improvement of manufacturing processes, not merely upon the ennobling of the individual character, but upon a third condition, namely, a clear understanding of the conditions of social life, on the part of both the capitalist and the operative, and their agreement upon common principles of social action. They must learn that social phenomena are as much the expression of natural laws as any others; that no social arrangements can be permanent unless they harmonize with the requirements of social statics and dynamics; and that, in the nature of things, there is an arbiter whose decisions execute themselves.

But this knowledge is only to be obtained by the application of the methods of investigation adopted in physical researches to the investigation of the phenomena of society. Hence, I confess, I should like to see one addition made to the excellent scheme of education propounded for the College, in the shape of provision for the teaching of Sociology. For though we are all agreed that party politics are to have no place in the instruction of the College; yet in this country, practically governed as it is now by universal suffrage, every man who

does his duty must exercise political functions. And, if the evils which are inseparable from the good of political liberty are to be checked, if the perpetual oscillation of nations between anarchy and despotism is to be replaced by the steady march of self-restraining freedom; it will be because men will gradually bring themselves to deal with political, as they now deal with scientific questions; to be as ashamed of undue haste and partisan prejudice in the one case as in the other; and to believe that the machinery of society is at least as delicate as that of a spinning jenny, and as little likely to be improved by the meddling of those who have not taken the trouble to master the principles of its action.

In conclusion, I am sure that I make myself the mouthpiece of all present in offering to the venerable founder of the Institution, which now commences its beneficent career, our congratulations on the completion of his work; and in expressing the conviction, that the remotest posterity will point to it as a crucial instance of the wisdom which natural piety leads all men to ascribe to their ancestors.

IX

ON SCIENCE AND ART IN RELATION TO EDUCATION

[This address was delivered to the members of the Liverpool Institute in 1882; and it may be considered as a continuation of the line of thought pursued by Huxley in the address on "Science and Culture," delivered two years earlier. It is a characteristic example of Huxley's own breadth of culture and of the range and variety of his interests—in letters, in music, in the fine arts, as well as in the several sciences wherein he was an indisputable master.

These three papers on education are closely related one to another; they deserve to be studied in connection with one another; and, taken together, they give us the whole of Huxley's theories as to what education ought to do. He declared his principles boldly and clearly; and even if he felt forced now and again to elucidate them by illustrations only local and temporary—that is to say, by examples of things as they were at the moment in Great Britain—the principles themselves are permanent in value and universal in application.]

IX

ON SCIENCE AND ART IN RELATION TO EDUCATION

[1882]

When a man is honored by such a request as that which reached me from the authorities of your institution some time ago, I think the first thing that occurs to him is that which occurred to those who were bidden to the feast in the Gospel—to begin to make an excuse; and probably all the excuses suggested on that famous occasion crop up in his mind one after the other, including his "having married a wife," as reasons for not doing what he is asked to do. But in my own case, and on this particular occasion, there were other difficulties of a sort peculiar to the time, and more or less personal to myself; because I felt that, if I came amongst you, I should be expected, and indeed, morally compelled, to speak upon the subject of Scientific Education. And then there arose in my mind the recollection of a fact, which probably no one here but myself remembers; namely, that some fourteen years ago I was the guest of a citizen of yours, who bears the honored name of Rathbone, at a very charming and pleasant dinner given

by the Philomathic Society; and I there and then, and in this very city, made a speech upon the topic of Scientific Education. Under these circumstances, you see, one runs two dangers—the first, of repeating oneself, although I may fairly hope that everybody has forgotten the fact I have just now mentioned, except myself; and the second, and even greater difficulty, is the danger of saying something different from what one said before, because then, however forgotten your previous speech may be, somebody finds out its existence, and there goes on that process so hateful to members of Parliament, which may be denoted by the term "Hansardization." Under these circumstances, I came to the conclusion that the best thing I could do was to take the bull by the horns, and to "Hansardize" myself—to put before you, in the briefest possible way, the three or four propositions which I endeavored to support on the occasion of the speech to which I have referred; and then to ask myself, supposing you were asking me, whether I had anything to retract or to modify in them, in virtue of the increased experience, and, let us charitably hope, the increased wisdom of an added fourteen years.

Now, the points to which I directed particular attention on that occasion were these: in the first place, that instruction in physical science supplies information of a character of especial value, both in a practical and a speculative point of view—information which cannot be obtained otherwise; and, in the second place, that, as educational discipline, it supplies, in a better form than any other study can supply, exercise in a special form of logic, and a peculiar method of testing the validity of

our processes of inquiry. I said further, that, even at that time, a great and increasing attention was being paid to physical science in our schools and colleges, and that, most assuredly, such attention must go on growing and increasing, until education in these matters occupied a very much larger share of the time which is given to teaching and training, than had been the case heretofore. And I threw all the strength of argumentation of which I was possessed into the support of these propositions. But I venture to remind you, also, of some other words I used at that time, and which I ask permission to read to you. They were these: "There are other forms of culture besides physical science, and I should be profoundly sorry to see the fact forgotten, or even to observe a tendency to starve or cripple literary or æsthetic culture for the sake of science. Such a narrow view of the nature of education has nothing to do with my firm conclusion that a complete and thorough scientific culture ought to be introduced into all schools."

I say I desire, in commenting upon these various points, and judging them as fairly as I can by the light of increased experience, to particularly emphasize this last, because I am told, although I assuredly do not know it of my own knowledge—though I think if the fact were so I ought to know it, being tolerably well acquainted with that which goes on in the scientific world, and which has gone on there for the last thirty years—that there is a kind of sect, or horde, of scientific Goths and Vandals, who think it would be proper and desirable to sweep away all other forms of culture and instruction, except those in physical science, and to make them the universal and

exclusive, or at any rate, the dominant training of the human mind of the future generation. This is not my view—I do not believe that it is anybody's view—but it is attributed to those who, like myself, advocate scientific education. I therefore dwell strongly upon the point, and I beg you to believe that the words I have just now read were by no means intended by me as a sop to the Cerberus of culture. I have not been in the habit of offering sops to any kind of Cerberus; but it was an expression of profound conviction on my own part—a conviction forced upon me not only by my mental constitution, but by the lessons of what is now becoming a somewhat long experience of varied conditions of life.

I am not about to trouble you with my autobiography; the omens are hardly favorable, at present, for work of that kind. But I should like if I may do so without appearing, what I earnestly desire not to be, egotistical—I should like to make it clear to you, that such notions as these, which are sometimes attributed to me, are, as I have said, inconsistent with my mental constitution, and still more inconsistent with the upshot of the teaching of my experience. For I can certainly claim for myself that sort of mental temperament which can say that nothing human comes amiss to it. I have never yet met with any branch of human knowledge which I have found unattractive—which it would not have been pleasant to me to follow, so far as I could go; and I have yet to meet with any form of art in which it has not been possible for me to take as acute a pleasure as, I believe, it is possible for men to take.

And with respect to the circumstances of life, it so hap-

pens that it has been my fate to know many lands and many climates, and to be familiar, by personal experience, with almost every form of society, from the uncivilized savage of Papua and Australia and the civilized savages of the slums and dens of the poverty-stricken parts of great cities, to those who perhaps, are occasionally the somewhat over-civilized members of our upper ten thousand. And I have never found, in any of these conditions of life, a deficiency of something which was attractive. Savagery has its pleasures, I assure you, as well as civilization, and I may even venture to confess—if you will not let a whisper of the matter get back to London, where I am known—I am even fain to confess, that sometimes in the din and throng of what is called "a brilliant reception" the vision crosses my mind of waking up from the soft plank which had afforded me satisfactory sleep during the hours of the night, in the bright dawn of a tropical morning, when my comrades were yet asleep, when every sound was hushed, except the little lap-lap of the ripples against the sides of the boat, and the distant twitter of the sea-bird on the reef. And when that vision crosses my mind, I am free to confess I desire to be back in the boat again. So that, if I share with those strange persons to whose asserted but still hypothetical existence I have referred, the want of appreciation of forms of culture other than the pursuit of physical science, all I can say is, that it is, in spite of my constitution, and in spite of my experience, that such should be my fate.

But now let me turn to another point, or rather to two other points, with which I propose to occupy myself. How far does the experience of the last fourteen years

justify the estimate which I ventured to put forward of the value of scientific culture, and of the share—the increasing share—which it must take in ordinary education? Happily, in respect to that matter, you need not rely upon my testimony. In the last half-dozen numbers of the "Journal of Education," you will find a series of very interesting and remarkable papers, by gentlemen who are practically engaged in the business of education in our great public and other schools, telling us what is doing in these schools, and what is their experience of the results of scientific education there, so far as it has gone. I am not going to trouble you with an abstract of those papers which are well worth your study in their fulness and completeness, but I have copied out one remarkable passage, because it seems to me so entirely to bear out what I have formerly ventured to say about the value of science, both as to its subject-matter and as to the discipline which the learning of science involves. It is from a paper by Mr. Worthington—one of the masters at Clifton, the reputation of which school you know well, and at the head of which is an old friend of mine, the Rev. Mr. Wilson—to whom much credit is due for being one of the first, as I can say from my own knowledge, to take up this question and work it into practical shape. What Mr. Worthington says is this:

"It is not easy to exaggerate the importance of the information imparted by certain branches of science; it modifies the whole criticism of life made in maturer years. The study has often, on a mass of boys, a certain influence which, I think, was hardly anticipated, and to which a good deal of value must

be attached—an influence as much moral as intellectual, which is shown in the increased and increasing respect for precision of statement, and for that form of veracity which consists in the acknowledgment of difficulties. It produces a real effect to find that Nature cannot be imposed upon, and the attention given to experimental lectures, at first superficial and curious only, soon becomes minute, serious, and practical."

Ladies and gentlemen, I could not have chosen better words to express—in fact, I have, in other words, expressed the same conviction in former days—what the influence of scientific teaching, if properly carried out, must be.

But now comes the question of properly carrying it out, because, when I hear the value of school teaching in physical science disputed, my first impulse is to ask the disputer, "What have you known about it?" and he generally tells me some lamentable case of failure. Then I ask, "What are the circumstances of the case, and how was the teaching carried out?" I remember, some few years ago, hearing of the head master of a large school, who had expressed great dissatisfaction with the adoption of the teaching of physical science—and that after experiment. But the experiment consisted in this—in asking one of the junior masters in the school to get up science, in order to teach it; and the young gentleman went away for a year and got up science and taught it. Well, I have no doubt that the result was as disappointing as the head master said it was, and I have no doubt that it ought to have been as disappointing, and far more disappointing too; for, if this kind of instruction is to

be of any good at all, if it is not to be less than no good, if it is to take the place of that which is already of some good, then there are several points which must be attended to.

And the first of these is the proper selection of topics, the second is practical teaching, the third is practical teachers, and the fourth is sufficiency of time. If these four points are not carefully attended to by anybody who undertakes the teaching of physical science in schools, my advice to him is, to let it alone. I will not dwell at any length upon the first point, because there is a general consensus of opinion as to the nature of the topics which should be chosen. The second point—practical teaching—is one of great importance, because it requires more capital to set it agoing, demands more time, and last, but by no means least, it requires much more personal exertion and trouble on the part of those professing to teach, than is the case with other kinds of instruction.

When I accepted the invitation to be here this evening, your secretary was good enough to send me the addresses which have been given by distinguished persons who have previously occupied this chair. I don't know whether he had a malicious desire to alarm me; but, however that may be, I read the addresses, and derived the greatest pleasure and profit from some of them, and from none more than from the one given by the great historian, Mr. Freeman, which delighted me most of all; and if I had not been ashamed of plagiarizing, and if I had not been sure of being found out, I should have been glad to have copied very much of what Mr. Free-

man said, simply putting in the word science for history. There was one notable passage: "The difference between good and bad teaching mainly consists in this, whether the words used are really clothed with a meaning or not." And Mr. Freeman gives a remarkable example of this. He says, when a little girl was asked where Turkey was, she answered that it was in the yard with the other fowls, and that showed she had a definite idea connected with the word Turkey, and was, so far, worthy of praise. I quite agree with that commendation; but what a curious thing it is that one should now find it necessary to urge that this is the be-all and end-all of scientific instruction—the *sine quâ non,* the absolutely necessary condition,—and yet that it was insisted upon more than two hundred years ago by one of the greatest men science ever possessed in this country, William Harvey. Harvey wrote, or at least published, only two small books, one of which is the well-known treatise on the circulation of the blood. The other, the "Exercitationes de Generatione," is less known, but not less remarkable. And not the least valuable part of it is the preface, in which there occurs this passage: "Those who, reading the words of authors, do not form sensible images of the things referred to, obtain no true ideas, but conceive false imaginations and inane phantasms." You see, William Harvey's words are just the same in substance as those of Mr. Freeman, only they happen to be rather more than two centuries older. So that what I am now saying has its application elsewhere than in science; but assuredly in science the condition of knowing, of your own knowl-

edge, things which you talk about, is absolutely imperative.

I remember, in my youth, there were detestable books which ought to have been burned by the hands of the common hangman, for they contained questions and answers to be learned by heart, of this sort, "What is a horse? The horse is termed *Equus caballus;* belongs to the class Mammalia; order, Pachydermata; family, Solidungula." Was any human being wiser for learning that magic formula? Was he not more foolish, inasmuch as he was deluded into taking words for knowledge? It is that kind of teaching that one wants to get rid of, and banished out of science. Make it as little as you like, but, unless that which is taught is based on actual observation and familiarity with facts, it is better left alone.

There are a great many people who imagine that elementary teaching might be properly carried out by teachers provided with only elementary knowledge. Let me assure you that that is the profoundest mistake in the world. There is nothing so difficult to do as to write a good elementary book, and there is nobody so hard to teach properly and well as people who know nothing about a subject, and I will tell you why. If I address an audience of persons who are occupied in the same line of work as myself, I can assume that they know a vast deal, and that they can find out the blunders I make. If they don't it is their fault and not mine; but when I appear before a body of people who know nothing about the matter, who take for gospel whatever I say, surely it becomes needful that I consider what I say, make sure

that it will bear examination, and that I do not impose upon the credulity of those who have faith in me. In the second place, it involves that difficult process of knowing what you know so well that you can talk about it as you can talk about your ordinary business. A man can always talk about his own business. He can always make it plain; but, if his knowledge is hearsay, he is afraid to go beyond what he has recollected, and put it before those that are ignorant in such a shape that they shall comprehend it. That is why, to be a good elementary teacher, to teach the elements of any subject, requires most careful consideration, if you are a master of the subject; and, if you are not a master of it, it is needful you should familiarize yourself with so much as you are called upon to teach—soak yourself in it, so to speak—until you know it as part of your daily life and daily knowledge, and then you will be able to teach anybody. That is what I mean by practical teachers, and, although the deficiency of such teachers is being remedied to a large extent, I think it is one which has long existed, and which has existed from no fault of those who undertook to teach, but because, until the last score of years, it absolutely was not possible for any one in a great many branches of science, whatever his desire might be, to get instruction which would enable him to be a good teacher of elementary things. All that is being rapidly altered, and I hope it will soon become a thing of the past.

The last point I have referred to is the question of the sufficiency of time. And here comes the rub. The teaching of science needs time, as any other subject; but it

needs more time proportionally than other subjects, for the amount of work obviously done, if the teaching is to be, as I have said, practical. Work done in a laboratory involves a good deal of expenditure of time without always an obvious result, because we do not see anything of that quiet process of soaking the facts into the mind, which takes place through the organs of the senses. On this ground there must be ample time given to science teaching. What that amount of time should be is a point which I need not discuss now; in fact, it is a point which cannot be settled until one has made up one's mind about various other questions.

All, then, that I have to ask for, on behalf of the scientific people, if I may venture to speak for more than myself, is that you should put scientific teaching into what statesmen call the condition of "the most favored nation"; that is to say, that it shall have as large a share of the time given to education as any other principal subject. You may say that that is a very vague statement, because the value of the allotment of time, under those circumstances, depends upon the number of principal subjects. It is x the time, and an unknown quantity of principal subjects dividing that, and science taking shares with the rest. That shows that we cannot deal with this question fully until we have made up our minds as to what the principal subjects of education ought to be.

I know quite well that launching myself into this discussion is a very dangerous operation; that it is a very large subject, and one which is difficult to deal with, however much I may trespass upon your patience in the

time allotted to me. But the discussion is so fundamental, it is so completely impossible to make up one's mind on these matters until one has settled the question, that I will even venture to make the experiment. A great lawyer-statesman and philosopher of a former age—I mean Francis Bacon—said that truth came out of error much more rapidly than it came out of confusion. There is a wonderful truth in that saying. Next to being right in this world, the best of all things is to be clearly and definitely wrong, because you will come out somewhere. If you go buzzing about between right and wrong, vibrating and fluctuating, you come out nowhere; but if you are absolutely and thoroughly and persistently wrong, you must, some of these days, have the extreme good fortune of knocking your head against a fact, and that sets you all straight again. So I will not trouble myself as to whether I may be right or wrong in what I am about to say, but at any rate I hope to be clear and definite; and then you will be able to judge for yourselves whether, in following out the train of thought I have to introduce, you knock your heads against facts or not.

I take it that the whole object of education is, in the first place, to train the faculties of the young in such a manner as to give their possessors the best chance of being happy and useful in their generation; and, in the second place, to furnish them with the most important portions of that immense capitalized experience of the human race which we call knowledge of various kinds. I am using the term knowledge in its widest possible sense; and the question is, what subjects to select by training and disci-

pline, in which the object I have just defined may be best attained.

I must call your attention further to this fact, that all the subjects of our thoughts—all feelings and propositions (leaving aside our sensations as the mere materials and occasions of thinking and feeling), all our mental furniture—may be classified under one of two heads—as either within the province of the intellect, something that can be put into propositions and affirmed or denied; or as within the province of feeling, or that which, before the name was defiled, was called the æsthetic side of our nature, and which can neither be proved nor disproved, but only felt and known.

According to the classification which I have put before you, then, the subjects of all knowledge are divisible into the two groups, matters of science and matters of art; for all things with which the reasoning faculty alone is occupied come under the province of science; and in the broadest sense, and not in the narrow and technical sense in which we are now accustomed to use the word art, all things feelable, all things which stir our emotions, come under the term of art, in the sense of the subject-matter of the æsthetic faculty. So that we are shut up to this—that the business of education is, in the first place, to provide the young with the means and the habit of observation; and, secondly, to supply the subject-matter of knowledge either in the shape of science or of art, or of both combined.

Now, it is a very remarkable fact—but it is true of most things in this world—that there is hardly anything one-sided, or of one nature; and it is not immediately

obvious what of the things that interest us may be regarded as pure science, and what may be regarded as pure art. It may be that there are some peculiarly constituted persons who, before they have advanced far into the depths of geometry, find artistic beauty about it; but, taking the generality of mankind, I think it may be said that, when they begin to learn mathematics, their whole souls are absorbed in tracing the connection between the premises and the conclusion, and that to them geometry is pure science. So I think it may be said that mechanics and osteology are pure science. On the other hand, melody in music is pure art. You cannot reason about it; there is no proposition involved in it. So, again, in the pictorial art, an arabesque, or a "harmony in gray," touches none but the æsthetic faculty. But a great mathematician, and even many persons who are not great mathematicians, will tell you that they derive immense pleasure from geometrical reasonings. Everybody knows mathematicians speak of solutions and problems as "elegant," and they tell you that a certain mass of mystic symbols is "beautiful, quite lovely." Well, you do not see it. They do see it, because the intellectual process, the process of comprehending the reasons symbolized by these figures and these signs, confers upon them a sort of pleasure, such as an artist has in visual symmetry. Take a science of which I may speak with more confidence, and which is the most attractive of those I am concerned with. It is what we call morphology, which consists in tracing out the unity in variety of the infinitely diversified structures of animals and plants. I cannot give you any example of a thorough æsthetic pleasure more in-

tensely real than a pleasure of this kind—the pleasure which arises in one's mind when a whole mass of different structures run into one harmony as the expression of a central law. That is where the province of art overlays and embraces the province of intellect. And, if I may venture to express an opinion on such a subject, the great majority of forms of art are not in a sense what I just now defined them to be—pure art; but they derive much of their quality from simultaneous and even unconscious excitement of the intellect.

When I was a boy, I was very fond of music, and I am so now; and it so happened that I had the opportunity of hearing much good music. Among other things, I had abundant opportunities of hearing that great old master, Sebastian Bach. I remember perfectly well—though I knew nothing about music then, and, I may add, know nothing whatever about it now—the intense satisfaction and delight which I had in listening, by the hour together, to Bach's fugues. It is a pleasure which remains with me, I am glad to think; but, of late years, I have tried to find out the why and wherefore, and it has often occurred to me that the pleasure derived from musical compositions of this kind is essentially of the same nature as that which is derived from pursuits which are commonly regarded as purely intellectual. I mean, that the source of pleasure is exactly the same as in most of my problems in morphology—that you have the theme in one of the old master's works followed out in all its endless variations, always appearing and always reminding you of unity in variety. So in painting; what is called "truth to nature" is the intellectual ele-

ment coming in, and truth to nature depends entirely upon the intellectual culture of the person to whom art is addressed. If you are in Australia, you may get credit for being a good artist—I mean among the natives—if you draw a kangaroo after a fashion. But, among men of higher civilization, the intellectual knowledge we possess brings its criticism into our appreciation of works of art, and we are obliged to satisfy it, as well as the mere sense of beauty in color and in outline. And so, the higher the culture and information of those whom art addresses, the more exact and precise must be what we call its "truth to nature."

If we turn to literature, the same thing is true, and you find works of literature which may be said to be pure art. A little song of Shakespeare or of Goethe is pure art; it is exquisitely beautiful, although its intellectual content may be nothing. A series of pictures is made to pass before your mind by the meaning of words, and the effect is a melody of ideas. Nevertheless, the great mass of the literature we esteem is valued, not merely because of having artistic form, but because of its intellectual content; and the value is the higher the more precise, distinct, and true is that intellectual content. And, if you will let me for a moment speak of the very highest forms of literature, do we not regard them as highest simply because the more we know the truer they seem, and the more competent we are to appreciate beauty the more beautiful they are? No man ever understands Shakespeare until he is old, though the youngest may admire him, the reason being that he satisfies the

artistic instinct of the youngest and harmonizes with the ripest and richest experience of the oldest.

I have said this much to draw your attention to what, in my mind, lies at the root of all this matter, and at the understanding of one another by the men of science on the one hand, and the men of literature, and history, and art, on the other. It is not a question whether one order of study or another should predominate. It is a question of what topics of education you shall select which will combine all the needful elements in such due proportion as to give the greatest amount of food, support, and encouragement to those faculties which enable us to appreciate truth, and to profit by those sources of innocent happiness which are open to us, and, at the same time, to avoid that which is bad, and coarse, and ugly, and keep clear of the multitude of pitfalls and dangers which beset those who break through the natural or moral laws.

I address myself, in this spirit, to the consideration of the question of the value of purely literary education? Is it good and sufficient, or is it insufficient and bad? Well, here I venture to say that there are literary educations, and literary educations. If I am to understand by that term the education that was current in the great majority of middle-class schools, and upper schools too, in this country when I was a boy, and which consisted absolutely and almost entirely in keeping boys for eight or ten years at learning the rules of Latin and Greek grammar, construing certain Latin and Greek authors, and possibly making verses which, had they been English verses, would have been condemned as abominable doggerel—if that is what you mean by literary education, then I say it is scandalous

ly insufficient and almost worthless. My reason for saying so is not from the point of view of science at all, but from the point of view of literature. I say the thing professes to be literary education that is not a literary education at all. It was not literature at all that was taught, but science in a very bad form. It is quite obvious that grammar is science and not literature. The analysis of a text by the help of the rules of grammar is just as much a scientific operation as the analysis of a chemical compound by the help of the rules of chemical analysis. There is nothing that appeals to the æsthetic faculty in that operation; and I ask multitudes of men of my own age, who went through this process, whether they ever had a conception of art or literature until they obtained it for themselves after leaving school? Then you may say, "If that is so, if the education was scientific, why cannot you be satisfied with it?" I say, because although it is a scientific training, it is of the most inadequate and inappropriate kind. If there is any good at all in scientific education it is that men should be trained, as I said before, to know things for themselves at first hand, and that they should understand every step of the reason of that which they do.

I desire to speak with the utmost respect of that science —philology—of which grammar is a part and parcel; yet everybody knows that grammar, as it is usually learned at school, affords no scientific training. It is taught just as you would teach the rules of chess or draughts. On the other hand, if I am to understand by a literary education the study of the literatures of either ancient or modern nations—but especially those of antiquity, and

especially that of ancient Greece; if this literature is studied, not merely from the point of view of philological science, and its practical application to the interpretation of texts, but as an exemplification of and commentary upon the principles of art; if you look upon the literature of a people as a chapter in the development of the human mind, if you work out this in a broad spirit, and with such collateral references to morals and politics, and physical geography, and the like as are needful to make you comprehend what the meaning of ancient literature and civilization is—then, assuredly, it affords a splendid and noble education. But I still think it is susceptible of improvement, and that no man will ever comprehend the real secret of the difference between the ancient world and our present time, unless he has learned to see the difference which the late development of physical science has made between the thought of this day and the thought of that, and he will never see that difference, unless he has some practical insight into some branches of physical science; and you must remember that a literary education such as that which I have just referred to, is out of the reach of those whose school life is cut short at sixteen or seventeen.

But, you will say, all this is fault-finding; let us hear what you have in the way of positive suggestion. Then I am bound to tell you that, if I could make a clean sweep of everything—I am very glad I cannot because I might, and probably should, make mistakes—but if I could make a clean sweep of everything and start afresh, I should, in the first place, secure that training of the young in reading and writing, and in the habit of attention and

observation, both to that which is told them, and that which they see, which everybody agrees to. But in addition to that I should make it absolutely necessary for everybody, for a longer or shorter period, to learn to draw. Now, you may say, there are some people who cannot draw, however much they may be taught. I deny that *in toto,* because I never yet met with anybody who could not learn to write. Writing is a form of drawing; therefore if you give the same attention and trouble to drawing as you do to writing, depend upon it, there is nobody who cannot be made to draw, more or less well. Do not misapprehend me. I do not say for one moment you would make an artistic draughtsman. Artists are not made; they grow. You may improve the natural faculty in that direction, but you cannot make it; but you can teach simple drawing, and you will find it an implement of learning of extreme value. I do not think its value can be exaggerated, because it gives you the means of training the young in attention and accuracy, which are the two things in which all mankind are more deficient than in any other mental quality whatever. The whole of my life has been spent in trying to give my proper attention to things and to be accurate, and I have not succeeded as well as I could wish; and other people, I am afraid, are not much more fortunate. You cannot begin this habit too early, and I consider there is nothing of so great a value as the habit of drawing, to secure those two desirable ends.

Then we come to the subject-matter, whether scientific or æsthetic, of education, and I should naturally have no question at all about teaching the elements of physical

science of the kind I have sketched, in a practical manner; but among scientific topics, using the word scientific in the broadest sense, I would also include the elements of the theory of morals and of that of political and social life, which, strangely enough, it never seems to occur to anybody to teach a child. I would have the history of our own country, and of all the influences which have been brought to bear upon it, with incidental geography, not as a mere chronicle of reigns and battles, but as a chapter in the development of the race, and the history of civilization.

Then with respect to æsthetic knowledge and discipline, we have happily in the English language one of the most magnificent storehouses of artistic beauty and of models of literary excellence which exists in the world at the present time. I have said before, and I repeat it here, that if a man cannot get literary culture of the highest kind out of his Bible, and Chaucer, and Shakespeare, and Milton, and Hobbes, and Bishop Berkeley, to mention only a few of our illustrious writers—I say, if he cannot get it out of those writers, he cannot get it out of anything; and I would assuredly devote a very large portion of the time of every English child to the careful study of the models of English writing of such varied and wonderful kind as we possess, and, what is still more important and still more neglected, the habit of using that language with precision, with force, and with art. I fancy we are almost the only nation in the world who seem to think that composition comes by nature. The French attend to their own language, the Germans study theirs; but Englishmen do not seem to think it is worth

their while. Nor would I fail to include, in the course of study I am sketching, translations of all the best works of antiquity, or of the modern world. It is a very desirable thing to read Homer in Greek; but if you don't happen to know Greek, the next best thing we can do is to read as good a translation of it as we have recently been furnished with in prose. You won't get all you would get from the original, but you may get a great deal; and to refuse to know this great deal because you cannot get all, seems to be as sensible as for a hungry man to refuse bread because he cannot get partridge. Finally, I would add instruction in either music or painting, or, if the child should be so unhappy, as sometimes happens, as to have no faculty for either of those, and no possibility of doing anything in any artistic sense with them, then I would see what could be done with literature alone; but I would provide, in the fullest sense, for the development of the æsthetic side of the mind. In my judgment, those are all the essentials of education for an English child. With that outfit, such as it might be made in the time given to education which is within the reach of nine-tenths of the population—with that outfit, an Englishman within the limits of English life, is fitted to go anywhere, to occupy the highest positions, to fill the highest offices of the State, and to become distinguished in practical pursuits, in science, or in art. For, if he have the opportunity to learn all those things, and have his mind disciplined in the various directions the teaching of those topics would have necessitated, then, assuredly, he will be able to pick up on his road through life, all the rest of the intellectual baggage he wants.

If the educational time at our disposition were sufficient there are one or two things I would add to those I have just now called the essentials; and perhaps you will be surprised to hear, though I hope you will not, that I should add, not more science, but one, or if possible, two languages. The knowledge of some other language than one's own is, in fact, of singular intellectual value. Many of the faults and mistakes of the ancient philosophers are traceable to the fact that they knew no language but their own, and were often led into confusing the symbol with the thought which it embodied. I think it is Locke who says that one-half of the mistakes of philosophers have arisen from questions about words; and one of the safest ways of delivering yourself from the bondage of words is, to know how ideas look in words to which you are not accustomed. That is one reason for the study of language; another reason is, that it opens new fields in art and in science. Another is the practical value of such knowledge; and yet another is this, that if your languages are properly chosen, from the time of learning the additional languages you will know your own language better than ever you did. So, I say, if the time given to education permits, add Latin and German. Latin, because it is the key to nearly one-half of English and to all the Romance languages; and German, because it is the key to almost all the remainder of English, and helps you to understand a race from whom most of us have sprung, and who have a character and a literature of a fateful force in the history of the world, such as probably has been allotted to those of no other people, except the Jews, the Greeks, and ourselves. Beyond

these, the essential and the eminently desirable elements of all education, let each man take up his special line—the historian devote himself to his history, the man of science to his science, the man of letters to his culture of that kind, and the artist to his special pursuit.

Bacon has prefaced some of his works with no more than this: *Franciscus Bacon sic cogitavit;* let "sic cogitavi" be the epilogue to what I have ventured to address to you to-night.

APPRECIATIONS

I

The supremacy of truth, the reality of things, the cultivation of the senses, the need for realistic education and understanding of the physical universe in the midst of which man is set, the folly of yielding to mere glamour, and the sin of sophisticating what we can perceive of truth by hope of reward or dread of consequence,—all this he strenuously fought for; and surely we may say that on the whole he won. No recognized branch of natural knowledge is now excluded from the contemplation by reasonable men, nor is stringent inquiry cursed or dreaded, even by those to whose general purview it appeared at one time to be alien. The universe is recognized as one; and loyal allegiance must be accorded to every proven fact.

—Sir Oliver Lodge

II

I know of no writing which by its mere form, even apart from the supreme interest of the matters with which it mostly deals, gives me so much pleasure as that of the author of these essays. In his case, more than that of his contemporaries, it is strictly true that the style is

the man. Some authors we may admire for the consummate skill with which they transfer to the reader their thought without allowing him, even for a moment, to be conscious of their personality. In Professor Huxley's work, on the other hand, we never miss his fascinating presence; now he is gravely shaking his head, now compressing the lips with emphasis, and from time to time, with a quiet twinkle of the eye, making unexpected apologies, or protesting that he is of a modest and peace-loving nature. At the same time, one becomes accustomed to a rare and delightful phenomenon: everything which has entered the author's brain by eye or ear, whether of recondite philosophy, biological fact, or political program, comes out again to us,—clarified, sifted, arranged and vivified by its passage through the logical machine of his strong individuality.

—Ray Lankester

III

An infinite capacity of taking pains—that, I think, he valued himself on. His literary work shows it in a degree not less than his scientific. He must be placed very high among contemporary writers. Contrast his style with that of the ordinary writer on science, who has no style, or with a very extraordinary man's, Darwin, who had a very bad style. Tyndall wrote admirably, with perhaps an exuberance of rhetoric inevitable to an Irishman. But Huxley dealt in the simplest, most lucid, most effective manner with the most difficult subjects. You were never at a loss for his meaning; if you were, it

was your fault, not his. He had a sobriety of ornament which was more to his taste and more to his readers' than the Corinthian style. He had vigor, and that imaginative use of language without which the full value of words is never brought out. He hated writing and forced himself to write, and also taught himself. Somewhere he tells how on his return, I think from the *Rattlesnake* voyage, he had all his material ready, which had cost him ten times more labor than the writing it out would require. But he could not bring himself to write. He early conquered that repugnance, though I doubt whether he ever wrote fluently or easily. I once asked him, "Oh, I can write fast enough, if that is all," was his answer, "but if it is anything important I take as much time as I need." A letter of his had just appeared in *The Times,* an important one on a controverted topic. I asked how much trouble he had taken with it. "Why, I wrote that over three times." The quality he valued most in style was, perhaps, precision. That and perfect clearness and perfect sincerity. About style as a separate quality of his writing he thought little. Subject and style were interfused. He had a certain declaration to make, a certain argument to conduct, a certain account to give of some matter which he thought important. Into the doing of this he put his whole soul. It was not enough to be accurate, he felt it his duty to say what had to be said in the way best calculated to appeal to the minds of his readers. He would not deliver his message, whatever it might be, in a halting or slipshod way. The

impulse of sincerity, coupled with an instinct for diction, and with long practice and unwearied effort, made him the admirable writer he was.

—George W. Smalley

IV

"Science and Literature," said Huxley, "are not two things, but two sides of one thing." An aphorism in an after-dinner speech must not be too literally construed, but the phrase indicates the quality which makes Huxley's writings as refreshing to the literary as to the scientific critic. "Exposition," he observes, "is not Darwin's *forte*. But there is a marvelous dumb sagacity about him like that of a sort of miraculous dog, and he gets to the truth by ways as dark as those of the Heathen Chinee." The final cause of Huxley might seem—though the theory is a little out of place—to have been the provision of an articulate utterance for Darwin's implicit logic. He points an old moral for young literary gentlemen in want of a style. He does not believe in moulding one's style by any other process than that of "striving after the expression of clear and definite conceptions." First, indeed, he adds, you have to catch your clear conceptions. I will not presume to say that for writers of a different category—Stevenson, for example—a different method may not be the right one. But most of us may heartily subscribe to Huxley's theory. The best way to be happy, as moralists tell us, is not to make the acquisition of happiness a conscious aim. To acquire a good style, you should never think of style at all. It will be

the spontaneous outcome of adequate expression of clear thought. Some writers, Huxley admits, might have learned dignity from a study of Hobbes, and concision from Swift and simplicity from Defoe and Goldsmith. The names are significant of his taste; but he learned by adopting the methods of his predecessors, not by imitating them as models. The labor which he bestowed upon his work is the more remarkable considering his quickness in seizing the right word in his hastiest letters. He speaks of writing essays half a dozen times before getting them into the right shape. He had the passion, unfortunately rare in Englishmen, for thorough logical symmetry. His "flashes" must be finished and concentrated. The happy phrase has to be fixed in the general framework. Arguments are terribly slippery things; one is always finding one's self shunted into some slightly diverging track of thought; and brilliant remarks are most dangerous seducers. They illustrate something, but then it is not quite the right thing. Huxley gets his Pegasus into the strictest subordination; but one can understand that he had to suppress a good many swervings to right and left, and only found the lucid order after experimental wanderings into the wrong paths. The result is the familiar one. What is easy to read has not, therefore, as the hasty reader infers, been easy to write. An "unfriendly" but surely rather simple-minded critic declared that the interest of Huxley's lectures was due not to the lecturer, but to the simplicity of the theory expounded. That is the effect which Swift produces in the "Drapier's Letters." He seems to be simply stating obvious facts. Huxley's best essays deserve to be put on a level with the finest ex-

amples of Swift or other great literary athletes; and any one who imagines the feat to be easy can try the experiment.

—Leslie Stephen

V

If absolute loyalty to truth, involving complete self-abnegation in face of the evidence, be the ideal aim of the scientific inquirer, there have been few men in whom that ideal has been so perfectly realized as in Huxley. If ever he were tempted by some fancied charm of speculation to swerve a hair's breadth from the strict line of fact, the temptation was promptly slaughtered and made no sign. For intellectual integrity he was a spotless Sir Galahad. I believe there was nothing in life which he dreaded so much as the sin of allowing his reason to be hoodwinked by personal predilections, or whatever Francis Bacon would have called "idols of the cave." Closely connected with this ever-present feeling was a holy horror of à priori convictions of logical necessity and of long festoons of deductive argument suspended from such airy supports. The prime necessity for him was to appeal at every step to observation and experiment, and in the absence of such verification to rest content with saying, "I do not know." It is to Huxley, I believe, that we owe the epithet *Agnostic*, for which all men of scientific proclivities owe him a debt of gratitude, since it happened to please the popular fancy, and at once supplanted the label *Positivist* which used to be ruthlessly pasted upon all such men, in spite of their protests and struggles. No better

word than *Agnostic* could be found to express Huxley's mental temperament, but with anything like a formulated system of agnosticism he had little more to do than with other "isms."

—John Fiske

CHRONOLOGY

1825	Huxley born May 4 at Ealing	Carlyle: "Life of Schiller"
		Waterton: "Wanderings of a Naturalist"
1826		Scott: "Woodstock"
		Cooper: "Last of the Mohicans"
1827		Keble: "The Christian Year"
1828		George Meredith and D. G. Rossetti born
1829		Catholic Emancipation Act
1830		Revolution in France
		Lyell: "Principles of Geology"
1831		E. Elliott: "Cornlaw Rhymes"
1832		Goethe and Scott died
1833	Huxley at school	Carlyle: "Sartor Resartus"
1834		Coleridge, Malthus, and Charles Lamb died

1835	Huxley's parents moved to Coombry	Tocqueville: "Democracy in America"
1836		James Mill died
1837		Queen Victoria crowned Carlyle: "French Revolution"
1838		Lecky and John Morley born
1839		Carlyle: "Chartism"
1840		Milman: "History of Christianity"
1841	Huxley studied medicine at Rotherhithe	Carlyle: "Hero Worship"
1842	Huxley entered Charing Cross Hospital	Darwin: "Coral Reefs"
1843		Mill: "Logic"
1844		Chambers: "Vestiges of Creation"
1845	Huxley won gold medal for anatomy and physiology; and received degree of Bachelor of Medicine	Hawthorne: "Mosses from an Old Manse"
1846	Huxley appointed assistant surgeon on the *Rattlesnake*	Repeal of the Corn Laws in England Famine in Ireland
1847	Huxley at Rio Janeiro and at Sydney	Thackeray: "Vanity Fair"
1848	Huxley in the Southern Pacific	Revolution in France
1849	Huxley in the Torres Straits	Emerson: "Representative Men"
1850	The *Rattlesnake* returned to England	Tennyson: "In Memoriam"

1851	Huxley elected to the Royal Society	
1852	Huxley received medal of Royal Society	Comte: "Positivist Catechism" Newman: "University Education"
1853		Wallace: "Travels on the Amazon"
1854	Huxley resigned from navy and was appointed lecturer in School of Mines and investigator on Geological Survey	Milman: "Latin Christianity"
1855	Huxley married; and began his lectures to Working Men	H. Spencer: "Principles of Psychology"
1856	Huxley: "Method of Paleontology"	Emerson: "English Traits"
1857		Buckle: "History of Civilization"
1858		Holmes: "Autocrat of the Breakfast Table"
1859		Darwin: "Origin of Species" Mill: "Liberty"
1860	Huxley answered Bishop Wilberforce at Oxford	Tyndall: "Glaciers of the Alps"
1861	Huxley began to edit the *Natural History Review*	Civil War in the United States Arnold: "On Translating Homer"

1862	Huxley appointed Professor at Royal College of Surgeons	Darwin: "Fertilization of Orchids" H. Spencer. "First Principles"
1863	Huxley: "Man's Place in Nature"	Thackeray died Lyell: "Antiquity of Man"
1864	Huxley: "Comparative Anatomy"	Hawthorne died Browning: "Dramatis Personæ"
1865		End of Civil War in the United States Arnold: "Essays in Criticism" Lecky: "History of Rationalism"
1866	Huxley: "Elementary Physiology"	Marx: "Capitalism"
1867		Faraday died Darwin: "Plants and Animals"
1868	Elected president of the Ethnological Society	Tyndall: "Faraday as a Discoverer"
1869	Huxley: "Classification of Animals" Elected president of the Geological Society	Galton: "Hereditary Genius"
1870	Huxley: "Lay Sermons" Elected president of British Association Founded Anthropological Institute	Franco-Prussian War Dickens died Tyndall: "Imagination in Science"

1871	Huxley: "Anatomy of Vertebrate Animals" Elected secretary of Royal Society	Darwin: "Descent of Man" Tylor: "Primitive Culture"
1872	Huxley in poor health. Trip to Egypt	Darwin: "Expression of the Emotions" H. Spencer: "Study of Sociology" Tyndall: "Forms of Water"
1873	Huxley: "Critiques and Addresses"	Arnold: "Literature and Dogma" Bagehot: "Physics and Politics"
1874		John Morley: "On Compromise"
1875	Huxley: "Elementary Biology"	Darwin: "Insectivorous Plants"
1876	Huxley lectured in the United States	Darwin: "Cross- and Self-Fertilization"
1877	Huxley: "Physiography" and "American Addresses"	Tolstoy: "Anna Karenina"
1878	Huxley: "Hume"	Joseph Henry died Lecky: "History of England"
1879	Huxley: "The Crayfish"	Lewes: "Study of Psychology"
1880	Huxley: "Science Primer"	George Eliot died
1881	Huxley: "Science and Culture" Appointed professor of Biology at Royal College of Science	Carlyle died Darwin: "Formulation of Vegetable Mould"

1882		Darwin and Emerson died
1883	Huxley elected president of the Royal Society	"Emerson-Carlyle Correspondence"
1884	Huxley in poor health. Vacation in Italy	Lang: "Custom and Myth"
1885	Huxley resigned official positions	Victor Hugo died
1886		Maine: "Popular Government"
1887		Renan: "People of Israel"
1888	Huxley received the Copley medal	Arnold died Browning died
1889	Huxley moved to Eastbourne	Bryce: "American Commonwealth" Wallace: "Darwinism"
1890	Huxley received the Linnean medal	Newman died
1891	Huxley: "Social Disease and Worse Remedies"	Lowell died
1892	Huxley: "Essays on Controverted Questions" Appointed to the Privy Council	Renan, Manning, and Tennyson died
1893	Huxley: "Evolution and Ethics" Revised edition of his works	Jowett and Tyndall died
1894	Huxley received Darwin medal	
1895	Huxley died at Eastbourne, June 29	

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